MECHANICAL ENGINEERING APPLICATIONS

INPUT

ABOUT INPUT

INPUT provides planning information, analysis, and recommendations to managers and executives in the information processing industries. Through market research, technology forecasting, and competitive analysis, INPUT supports client management in making informed decisions. Continuing services are provided to users and vendors of computers, communications, and office products and services.

The company carries out continuous and in-depth research. Working closely with clients on important issues, INPUT's staff members analyze and interpret the research data, then develop recommendations and innovative ideas to meet clients' needs. Clients receive reports, presentations, access to data on which analyses are based, and continuous consulting.

Many of INPUT's professional staff members have nearly 20 years experience in their areas of specialization. Most have held senior management positions in operations, marketing, or planning. This expertise enables INPUT to supply practical solutions to complex business problems.

Formed in 1974, INPUT has become a leading international consulting firm. Clients include over 100 of the world's largest and most technically advanced companies.

OFFICES

Headquarters
2471 East Bayshore Road
Suite 600
Palo Alto, California 94303
(415) 493-1600
Telex 171407

Dallas
Campbell Center II
8150 N. Central Expressway
Dallas, Texas 75206
(214) 691-8565

New York
Park 80 Plaza West-I
Saddle Brook, New Jersey 07662
(201) 368-9471

UNITED KINGDOM
INPUT, Ltd.
Airwork House (4th Floor)
35 Piccadilly
London, W.1.
England
01-439-4442
Telex 269776

JAPAN
INPUT Japan
Suite 1106
7-7-26 Nishi-Shinjuku
Tokyo
Japan 160
(03) 371-3082

AFFILIATES

Australia
Infocom Australia
Highland Centre, 7-9 Merriwa St.,
P.O. Box 110,
Gordon N.S.W. 2072
(02) 498-8199
Telex AA 24434

Italy
PCP Sistema SRL
20127 Milano
Via Soperga 36
Italy
Milan 284-2850

INPUT Planning Services for Management

IMPROVING THE PRODUCTIVITY OF ENGINEERING AND MANUFACTURING USING CAD/CAM

MECHANICAL ENGINEERING APPLICATIONS

A Multiclient Study

DECEMBER 1981

IMPROVING THE PRODUCTIVITY OF ENGINEERING AND MANUFACTURING USING CAD/CAM
MECHANICAL ENGINEERING APPLICATIONS

CONTENTS

IMPROVING THE PRODUCTIVITY OF ENGINEERING AND MANUFACTURING USING CAD/CAM
MECHANICAL ENGINEERING APPLICATIONS

EXHIBITS

I INTRODUCTION AND SCOPE

I INTRODUCTION AND SCOPE

A. INTRODUCTION

- This report, produced by INPUT as part of a five volume CAD/CAM (Computer-Aided Design/Computer Aided Manufacturing) multiclient study, analyzes the application of CAD/CAM systems to mechanical products.

- The results of 76 user interviews are presented in this report.
  - There were 33 on-site interviews and 43 telephone interviews.

- The purpose of this study is to understand the experiences and needs of users of CAD/CAM for mechanical applications.
  - Who are the users?
  - What features were most important to their CAD/CAM system selection?
  - What benefits are being realized?
  - What are the users' views of important trends in CAD/CAM?

- What are the plans for future expansion of their CAD/CAM installations?

- About 40% of the exhibits in the report display data in a manner designed to eliminate data which deviate from the mean by an extreme amount.

  - These exhibits are designated by the legend "Note: 10% of the highest and 10% of the lowest responses were eliminated from these exhibits."

  - The exhibits show only the central 80% of the respondents' data.

    . Ten percent of the highest respondent values were eliminated.

    . Ten percent of the lowest respondent values were also eliminated.

  - The remaining 80% represent all of the data that is approximately within plus or minus one standard deviation from the arithmetic mean.

  - The arithmetic mean is represented by a heavy line drawn through the portrayed range and its value is printed next to the line.

  - The first occurance of this representation of the data is in Exhibit II-3.

    . This exhibit shows that 80% of the respondents expected from 100% to 300% gain in productivity from CAD with a mean of 218%.

    . The range in achieved productivity gain for 80% of the respondents was from 50% to 350% with a mean of 237%.

- A copy of the questionnaire is included in Appendix A.

- Reviews of vendor literature and follow-up interviews were used in addition to the questionnaire in preparing to this report.

- Case studies of selected users of mechanical CAD/CAM systems are presented in Appendix B.

B. SCOPE

- U.S. and international companies and organizations using mechanical CAD/CAM systems were surveyed.

  - A total of 61 interviews were held with U.S. organizations using CAD/CAM, nine with European, and six with Japanese.

- Division of the mechanical users by type of product illuminated differences in their experience and needs.

  - These product categories are: discrete mechanical products, mobile transportation products, and aerospace products.

- CAD/CAM systems reported include: turnkey CAD systems, CAD systems associated with mainframe computers, custom or in-house developed CAD/CAM systems, and remote timesharing services for CAD or CAM.

- The application of CAD/CAM to design, analysis, documentation, manufacturing, and engineering management was considered.

- Present and future applications and trends through 1986 and 1990 were surveyed.

II EXECUTIVE SUMMARY

- Of the 76 organizations surveyed for this report, 39 produce mechanical products categorized as "discrete," 15 produce mobile-transportation products, 14 produce aerospace products, and 8 produce products for "other" services (e.g., government, universities, etc.).

- Organizations producing discrete mechanical products currently have small CAD installations, averaging five workstations. These are typically turnkey CAD systems.

- Aerospace organizations have large installations, averaging 53 workstations. Turnkey CAD systems are extensively used in aerospace, but computer supplier-based CAD systems and in-house developed CAD systems are also used extensively.

- Organizations producing mobile-transportation products average 17 workstations per installation and are intermediate in configuration size between the discrete and aerospace categories. These organizations also make extensive use of all three types of CAD systems: turnkey, computer supplier-based, and in-house developed.

- Timesharing services have less use in the organizations surveyed. When used, these services are for structural analysis and numerically controlled (NC) tasks. Commercial software packages for these tasks are also purchased and used on in-house mainframes.

- Computervision, IBM-CADAM, Applicon, and Auto-trol installations were the most frequently reported. These accounted for 66 out of 91 CAD system installations.

A. IMPORTANT FACTORS AND BENEFITS

- As shown in Exhibit II-1, the most important factors used to select CAD systems were the capabilities of its software and its flexibility.

- Cost was the least important factor, usually by a wide margin.

- The productivity improvement in drawings per drafting/designer man-hour was the most important realized benefit.

- Improved quality of design was also an important benefit but lagged behind productivity.

- The lowest rated benefit was being able to do designs with CAD that cannot be done without it. In general, CAD today is considered not as a means of providing unique design capabilities but as a tool to increase productivity.

B. PRESENT APPLICATIONS AND FUTURE NEEDS

- Exhibit II-2 shows the major application tasks for mechanical CAD/CAM systems. Drafting (and documentation) is the predominant application today.

- The response time of the CAD system is an important factor in determining its drafting productivity. One-half of the users were dissatisfied with the response of their systems.

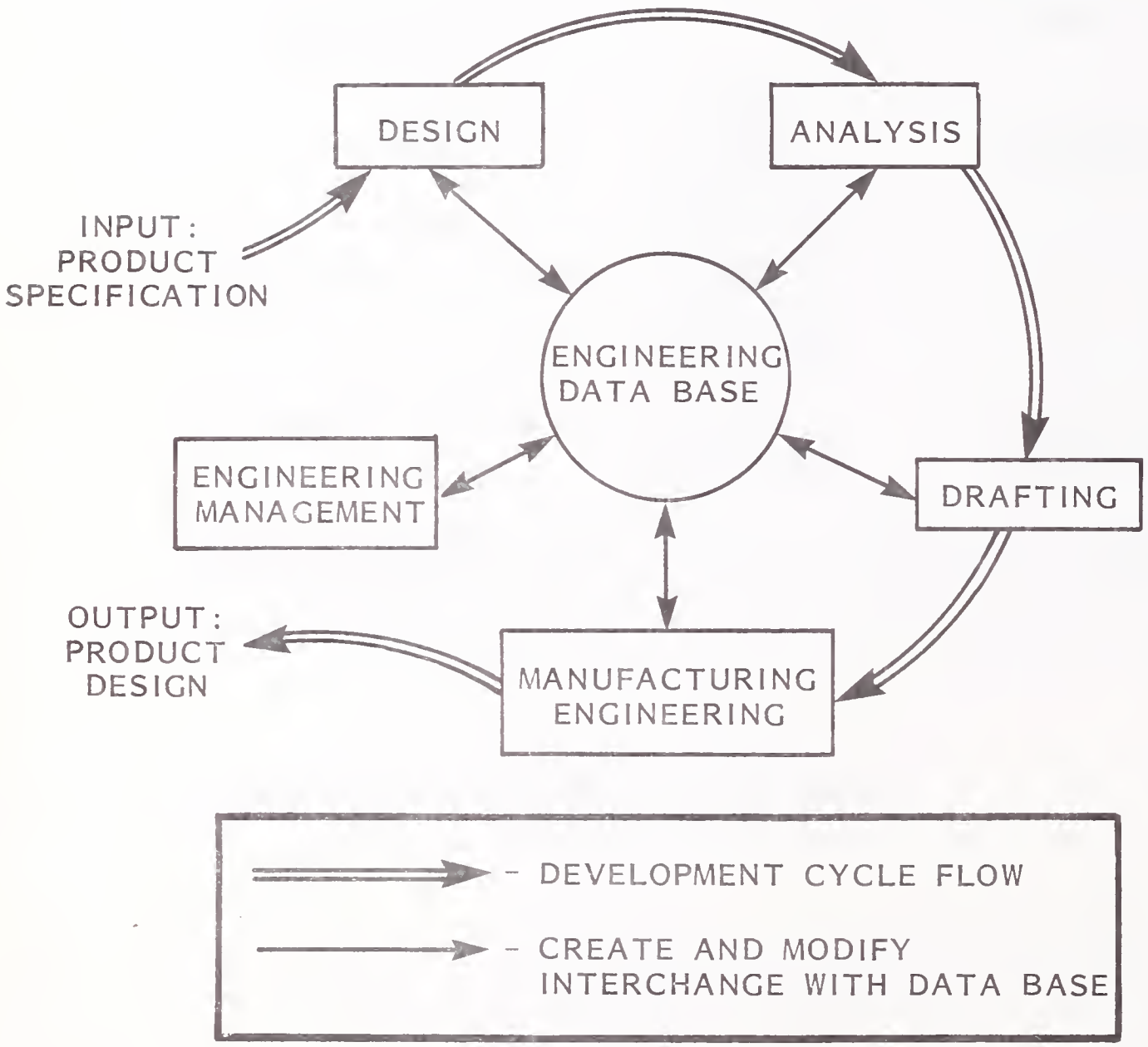
EXHIBIT II-1

CAD SELECTION FACTORS AND BENEFITS

CAD SELECTION FACTORS		CAD BENEFITS REALIZED
• Software	MOST IMPORTANT	• Productivity Improvement
• System Flexibility		• Design Quality
• Access to Data Base	LEAST IMPORTANT	• Plant Loading
• Cost		• Cannot do Design Without CAD

EXHIBIT II-2

MECHANICAL ENGINEERING PROCESS



- Response degrades severely with loading (by increasing the number of workstations or increasing the size of the data base).

- The required response time for immediate commands is less than two seconds.

- Achieved drafting productivity gains average more than expected, as shown in Exhibit II-3. There is a wider spread in achieved results than expected and many users reported less than expected.

- Training of operators is an important factor in determining productivity.

  - The initial training period is short, averaging three weeks.

  - The time to reach full proficiency is long, averaging 19 weeks. Reduction of this time is an opportunity to get more out of CAD.

  - There is not much difference between systems from CAD vendors in reported training times. Applicon and IBM-CADAM have slightly better reported times.

- Mechanical users believe that a "drawing-less" factory will come, but it will not be a fully achieved goal until 1990.

  - Some users think this goal will be achieved sooner.

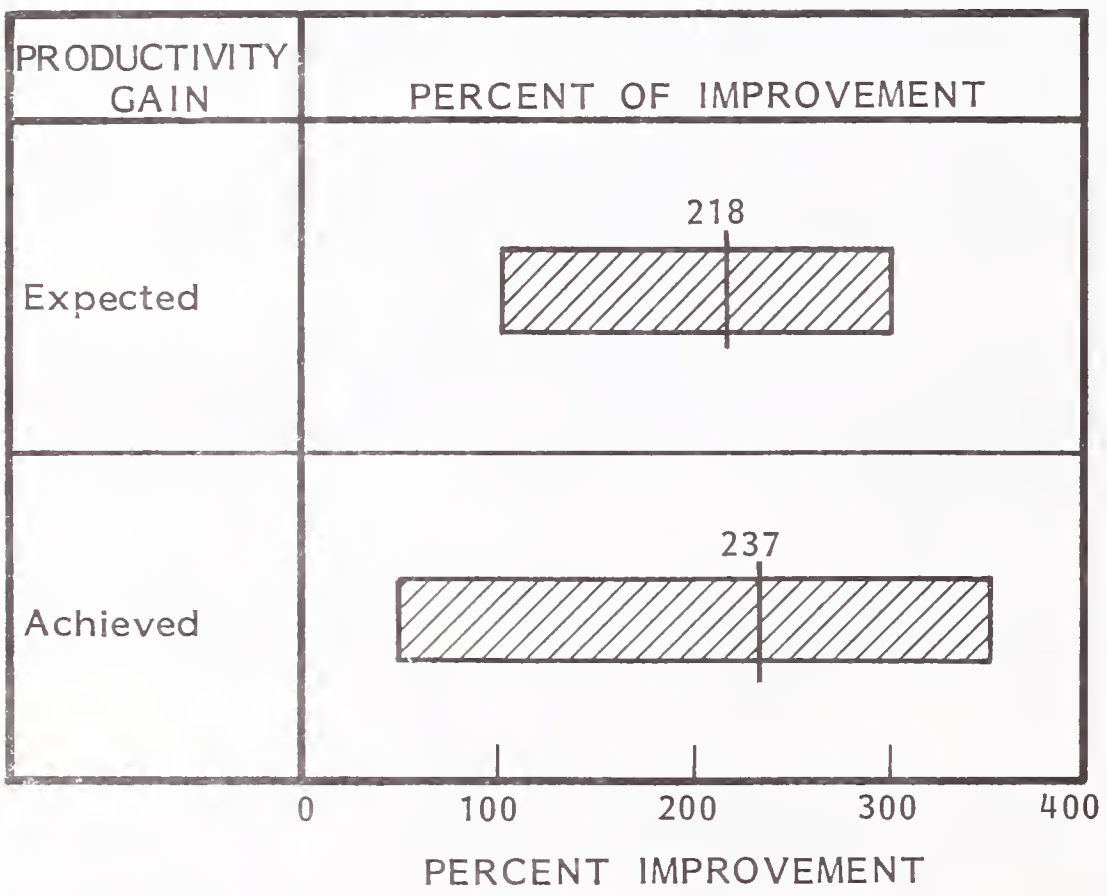
- For design tasks, as shown in Exhibit II-4, users rate true 3-D geometry and dynamic motion as important, almost essential, capabilities for CAD systems by 1986.

  - Fifty percent of the users rated 3-D geometry as essential.

  - Dynamic motion was slightly less important but still essential to 17% of the users.

EXHIBIT II-3

REPORTED PRODUCTIVITY GAINS FOR CAD



NOTE: 10% of the highest and 10% of the lowest responses were eliminated from this exhibit.

EXHIBIT II-4

IMPORTANCE TO USERS OF "TRUE" 3-D GEOMETRY AND DYNAMIC MOTION IN 1986

DESIGN TASK	RATING	PERCENT OF RESPONDENTS GIVING 10 RATING
True 3-D Geometry	7.7	50%
Dynamic Motion	6.2	17%

1 2 3 4 5 6 7 8 9 10

1 = Not Needed, 5 = Some Need, 10 = Essential

NOTE: 10% of the highest and 10% of the lowest responses were eliminated from this exhibit.

- One hundred percent of the aerospace users expect to be using volumetric (or solids) modeling by 1986. High percentages of the mobile/transportation and discrete product users also expect to be using it. This is shown in Exhibit II-5.

  - Productive and reliable volumetric modeling systems may not be as far along as these users expect by this date.

- Analysis is performed on diverse software and hardware systems. Most of the processing of intensive finite element analysis is done on in-house mainframe processors or with remote timesharing services.

- Fast growth in the use of analysis processing is expected before 1986. By 1986, the number of organizations that consider finite element analysis essential to their CAD/CAM systems will double, 33% compared to 17% who consider it essential now.

- Manufacturing applications are rapidly increasing in importance and are expected to be closely integrated with CAD.

- As shown in Exhibit II-6, NC received the strongest 1986 rating as an integrated CAD/CAM function. The fraction of users who consider NC functions essential by 1986 is 49%, almost double those who rate it essential now.

C. CAD/CAM TRENDS

- Calligraphic (or vector-refresh) and raster displays are judged to be strongly needed by 1986, as shown in Exhibit II-7.

  - An increase in the resolution of raster displays to 2000 x 2000 lines is required.

EXHIBIT II-5

RESPONDENTS' EXPECTED USE OF VOLUMETRIC MODELS IN 1986

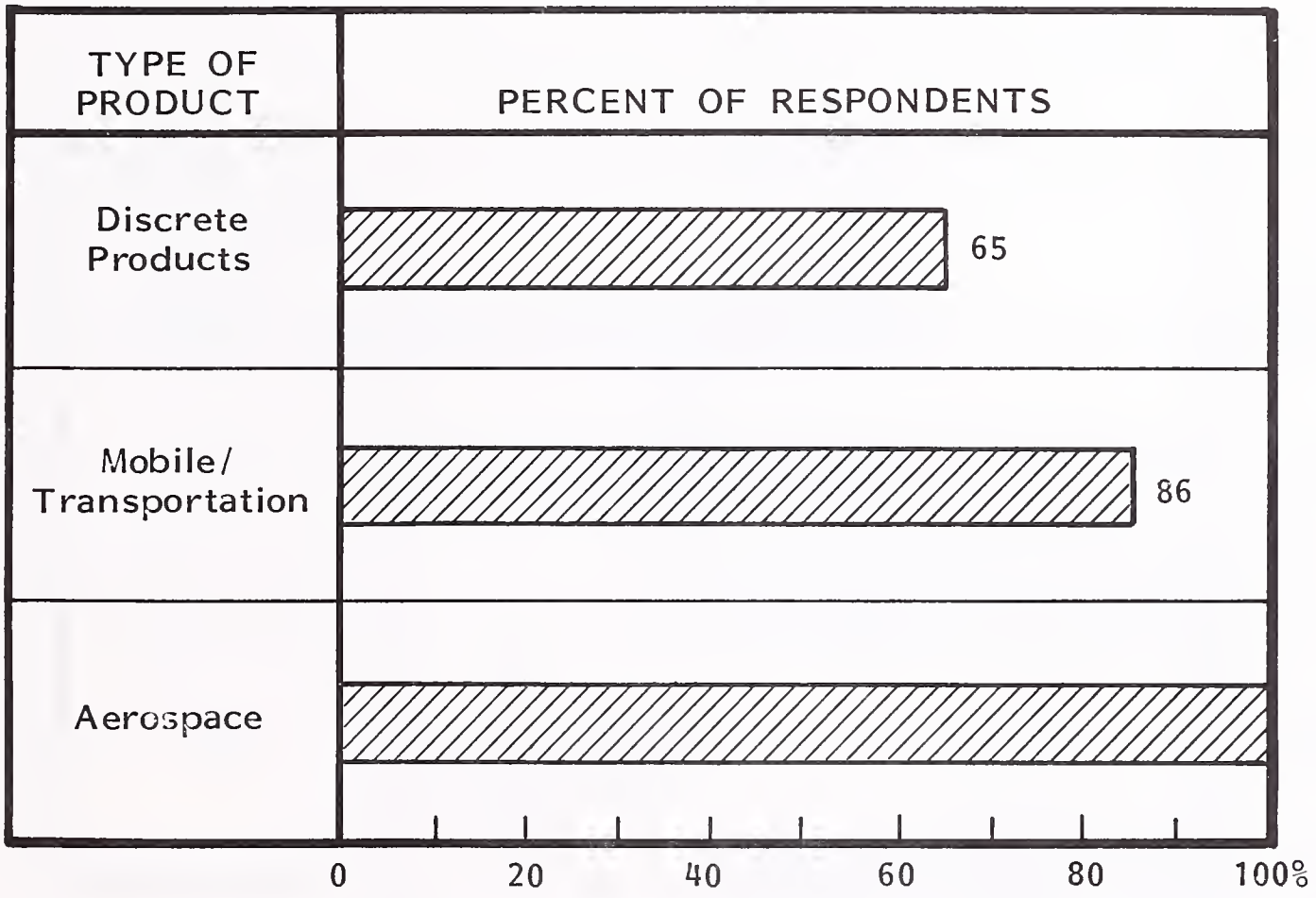
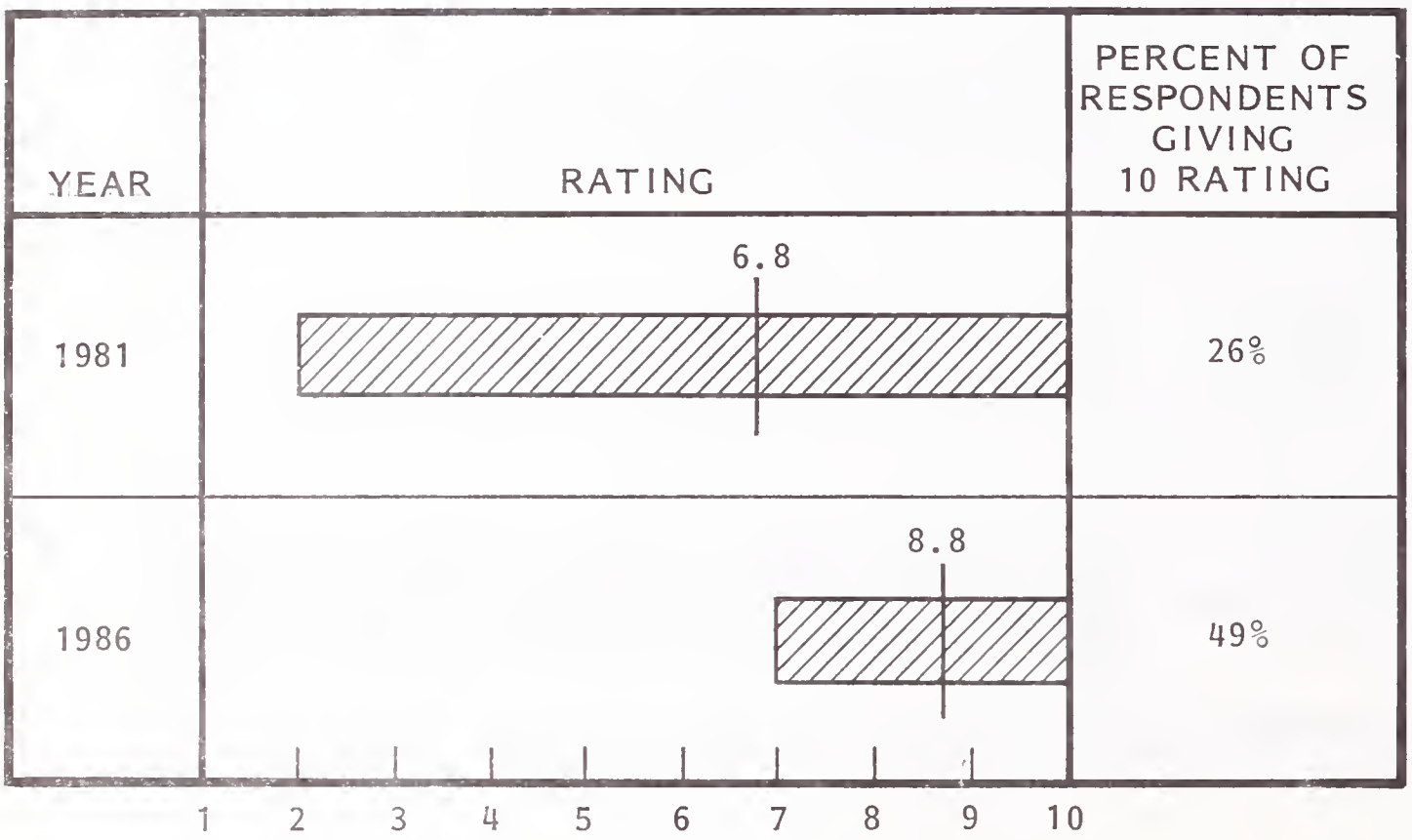


EXHIBIT II-6

RESPONDENT'S RATINGS OF IMPORTANCE OF
NUMERICALLY CONTROLLED FUNCTIONS INTEGRATED WITH CAD

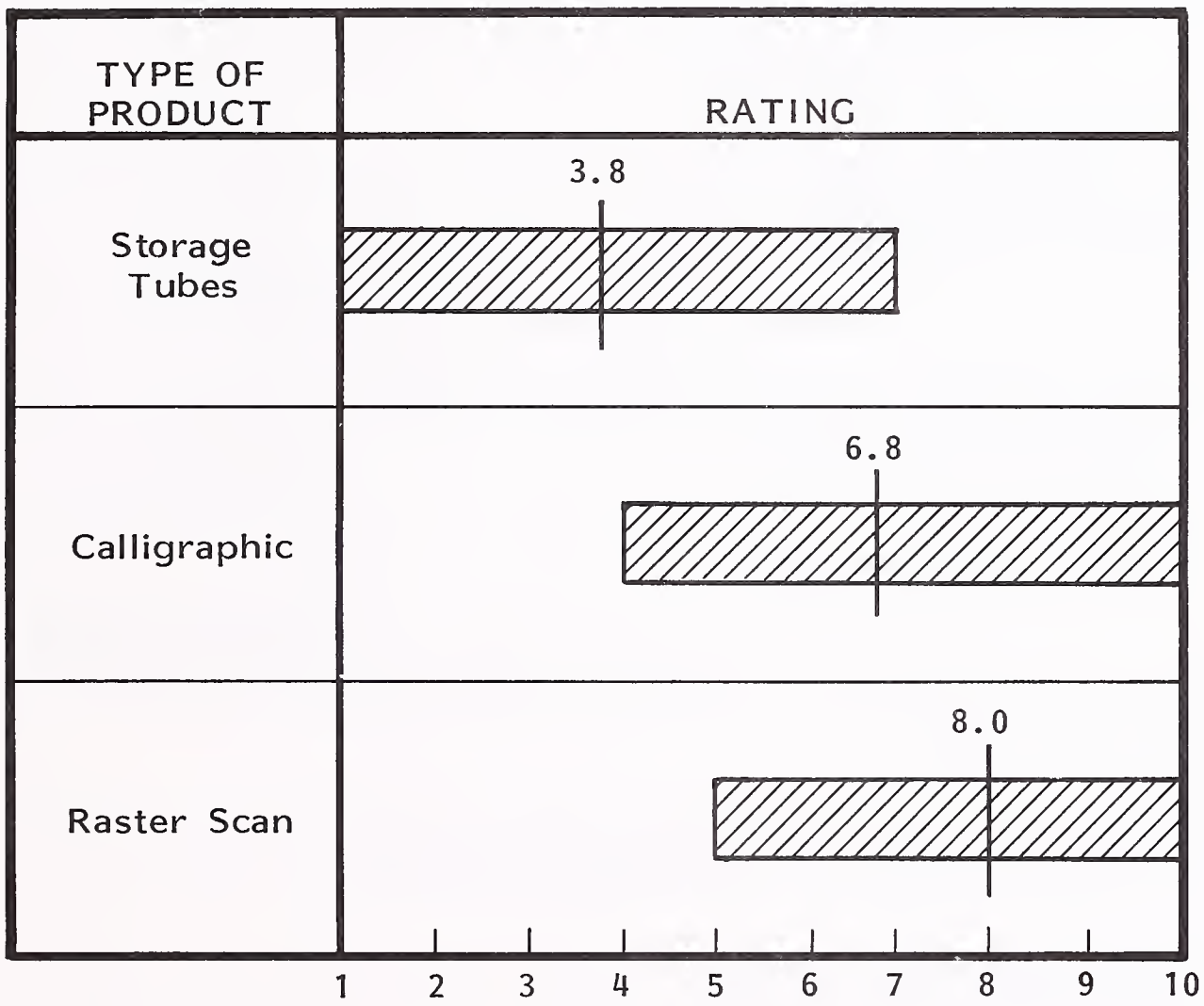


1 = Not Needed, 5 = Some Need, 10 = Essential

NOTE: 10% of the highest and 10% of the lowest responses were eliminated from this exhibit.

EXHIBIT II-7

RESPONDENTS' RATINGS OF ADAQUACY OF DISPLAY TO THEIR APPLICATION IN 1986



1 = Inadequate, 10 = Exceeds Needs

NOTE: 10% of the highest and 10% of the lowest responses were eliminated from this exhibit.

- Color is also a strong need by 1986.

- Intelligent workstations are an expected CAD system addition. These workstations will serve remote locations and will decrease the loading on the central CAD computer or mainframe.

- Users continue to expect further and significant improvements in workstation performance at lower cost.

- Software improvements expected include:

  - Improved surface modeling.

  - Volumetric modeling.

  - Improved finite element mesh generation procedures.

  - Improved NC capabilities.

  - Better system response.

- There is a strong need for effective communication standards to allow interchange of data:

  - Between CAD systems from different vendors.

  - From CAD into NC systems.

  - Between CAD and host or mainframe computers.

- Initial Graphics Exchange Specification (IGES) is expected to provide this communication standard.

- Graphics Kernel System (GKS) may be a separate standard for European users.

- The willingness of CAD vendors to provide operational IGES capabilities to interchange data with competitive systems is questionable.

- Integration of all CAD and CAM systems is important and is considered to have a high payoff by the mechanical users. Exhibit II-8 shows the obstacles to integration that are considered important and not important by users.

  - Organization, particularly the classic divisions between engineering and manufacturing, is the most important obstacle.

  - Incompatibility between specialized CAD and CAM systems, and the need for communication standards such as IGES are rated as important obstacles.

  - Unproven benefits and security are not considered to be important obstacles.

D. USERS' PLANS

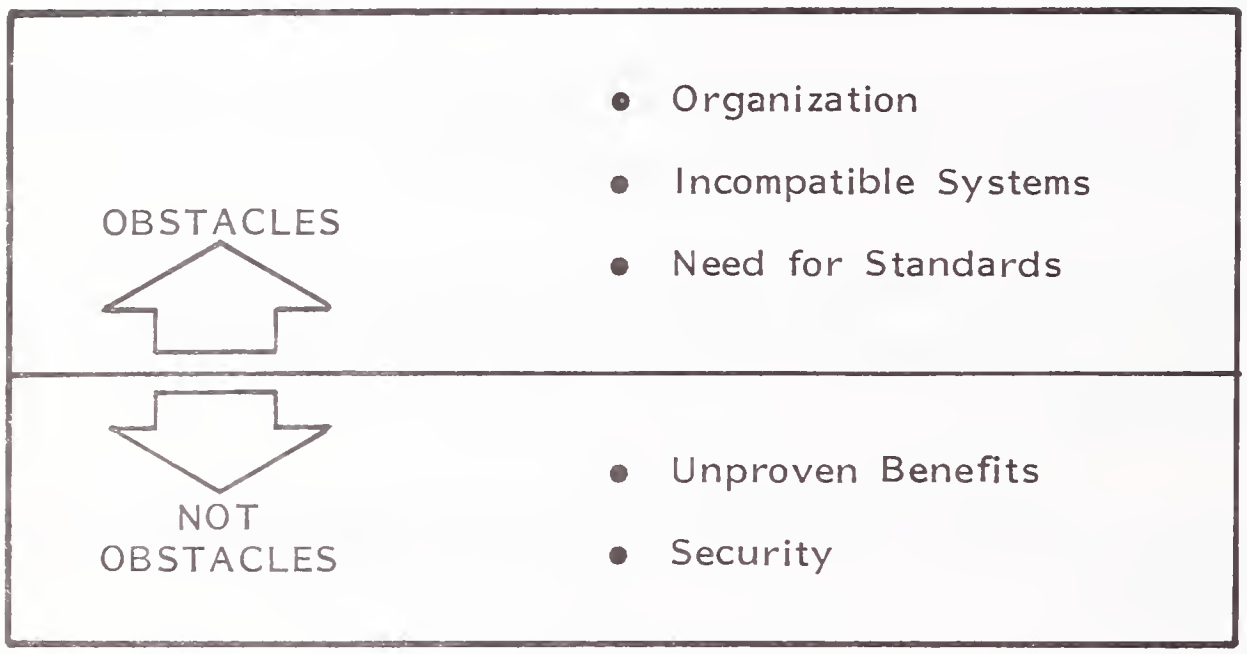
- The users are generally satisfied with CAD systems. Almost 90% stated that their CAD systems met or exceeded their expectations.

- Users were asked if they would buy from the same vendor again. More than 70% answered yes.

  - This question was worded in the past tense and leaves the door open regarding future procurements.

EXHIBIT II-8

OBSTACLES TO CAD/CAM INTEGRATION



- Without a fully effective IGES (or equivalent), many users are "locked in" to their present CAD vendor. Multiple CAD systems within one installation without communication between them are undesirable.

- The market strategy of CAD vendors recognizes the value of the "initial" position in a company, or within a division of a company. There is intense competition for these initial installations.

- Many large companies have CAD installations from multiple vendors. These companies have been pioneering proponents of IGES, or have developed their own intersystem communication standards.

- Almost all users interviewed plan further, significant expansion of their CAD/CAM systems through 1986.

  - Large installations will grow.

  - Many small installations will more than double in size.

- The number of terminals and workstations will be increased.

- Some of the expansion will be upgrading.

  - Color raster terminals and workstations with dynamic capabilities will be added.

- Major software purchases will be part of the expansion. These purchases will include software for improved design, analysis, and manufacturing capabilities.

- Investments and purchases will be made to obtain more fully integrated CAD/CAM systems using a common engineering data base.

III SURVEY RESULTS

III SURVEY RESULTS

- This chapter discusses survey results which are relevant to all mechanical engineering applications.

- Major application areas within mechanical engineering are: mechanical design definition, analysis, documentation, manufacturing engineering, and engineering management. Sections B through F cover these applications.

A. GENERAL RESULTS

1. SURVEY COVERAGE

- There were 76 companies and organizations surveyed for mechanical engineering applications. Exhibit III-1 shows the distribution of these interviews by location (on-site or telephone); location of the company in the U.S., Europe, or Japan; and the type of mechanical product produced.

- The product categories - Discrete, Mobile/Transportation, and Aerospace, were chosen to distinguish major differences in survey results which may be dependent on the complexity and type of product being designed. Exhibit III-2 lists examples of products in each category.

  - Later analysis shows that the aerospace category is distinctly different.

EXHIBIT III-1

DISTRIBUTION OF MECHANICAL ENGINEERING APPLICATION INTERVIEWS

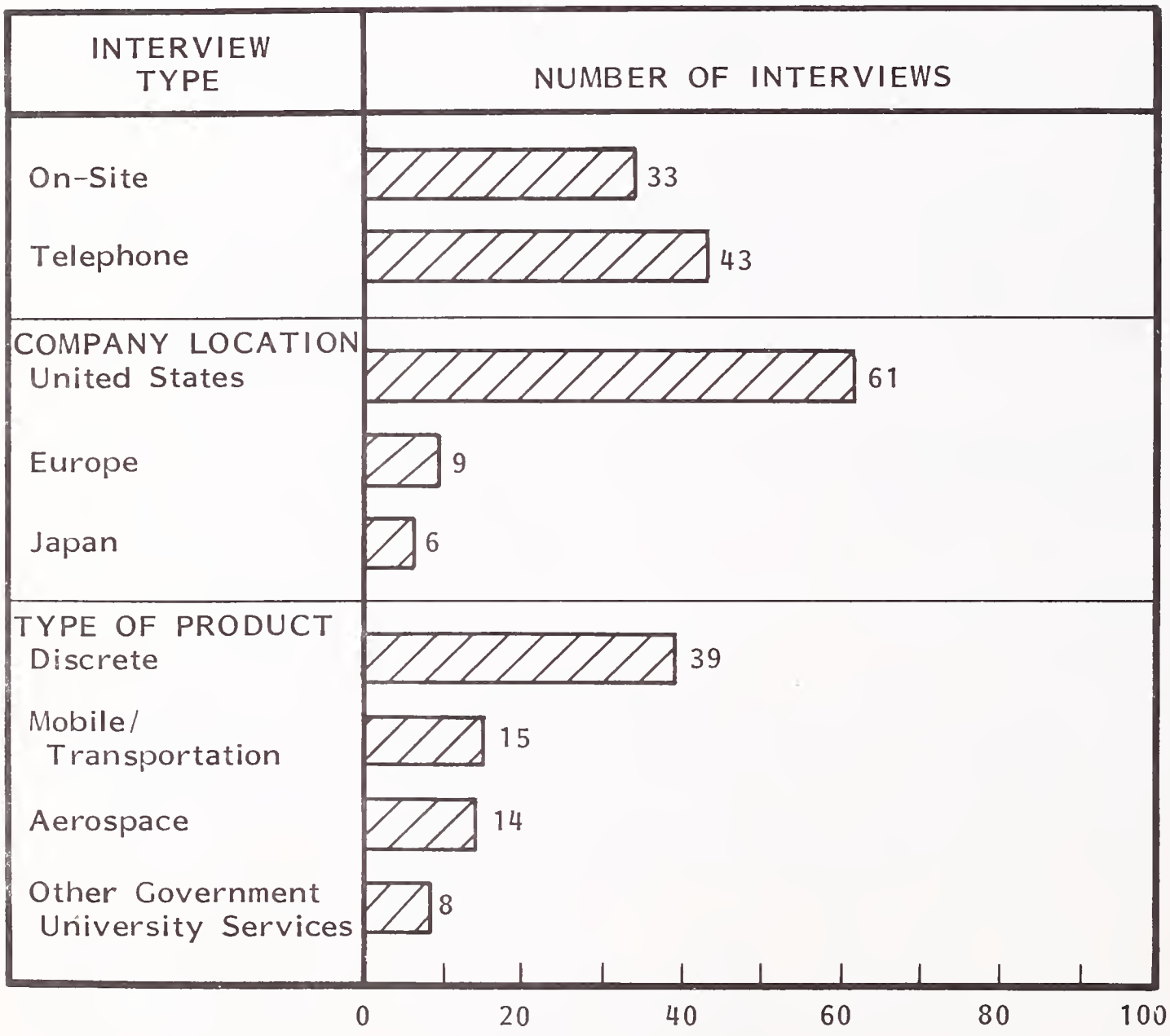


EXHIBIT III-2

REPRESENTATIVE PRODUCTS

DISCRETE

- Steel Doors, Towers
- Material Handling and Processing
- Printing and Paper Handling Equipment
- Conveyors, Cable Belts
- Heavy Industrial Motors
- Industrial Controls
- Power Transmission
- Bakery Equipment
- Air Cleaners, Mufflers
- Electric Valves
- Aircraft, Automotive Components
- Molds, Castings
- Pistons
- Pumps
- Lens Systems
- Power Tools
- Rubber Tires

MOBILE - TRANSPORTATION

- Passenger Cars
- Trucks
- Frames and Bodies
- Vehicle Transmissions
- Farm Machinery
- Off Highway Equipment
- Elevating Systems
- Ship Hulls
- Heavy Construction Equipment

AEROSPACE

- Private Airplanes
- Business Airplanes
- Commercial Airplanes
- Spacecraft
- Missiles
- Aircraft Turbine Engines
- Military Aircraft

OTHER

- Government Agencies
- Universities
- CAD and Engineering Services

- Similarly, the mobile/transportation category has intermediate characteristics between the aerospace and discrete manufacturing industries.

- CAD/CAM service bureaus are becoming an important segment with unique needs. Only a few such service bureaus were included in this survey. Additional priority should be given this category in the follow-on research.

- Further research into differences in CAD/CAM needs and usage for the discrete product category has been recommended by a member of the INPUT university panel.

  - Three levels of production volume should be established:

    . Batch (1 to 1,000 units).

    . Serial (1,000 to 10,000 units).

    . Mass production (greater than 10,000 units).

  - Different needs and usage patterns can be expected, but were not specifically measured in the INPUT study.

  - INPUT will consider this topic for follow-on research.

2. TYPE OF CAD/CAM SYSTEM USED

- The use of turnkey, computer supplier, custom, or remote CAD systems reported by each organization surveyed is tabulated in Exhibit III-3. Most organizations use more than one type and, as noted below, each category covers different CAD/CAM functions.

EXHIBIT III-3

REPORTED CAD USAGE BY
NUMBER OF RESPONDENTS

PRODUCT CATEGORY	TYPE OF CAD SYSTEM			
	TURNKEY	COMPUTER SUPPLIER	IN-HOUSE OR CUSTOM	REMOTE COMPUTER SERVICES
Discrete	29	7	14	7
Mobile/ Transportation	11	4	10	5
Aerospace	9	7	9	2
Other	7	0	2	1
All Respondents	56	18	35	15

- Most turnkey CAD systems are used for drafting functions, although some respondents are using these systems for design layout, analysis, and NC.

- Computer supplier-based CAD systems are typically multistation systems operating with a host or mainframe computer. They are purchased and supported by the mainframe vendor. Most of those reported are IBM-CADAM installations.

- In-house, or custom, CAD covers a mixture of CAD applications. For some respondents, this includes any use of computers for engineering and analysis. Very few respondents reported interactive drafting in this category.

- Remote computing services for the most part are the use of these services for engineering analysis and, in some cases, for NC.

- Exhibit III-4 shows the percentage use of each CAD type by user product category. These data show a different pattern for discrete, mobile/ transportation, and aerospace product manufacturers.

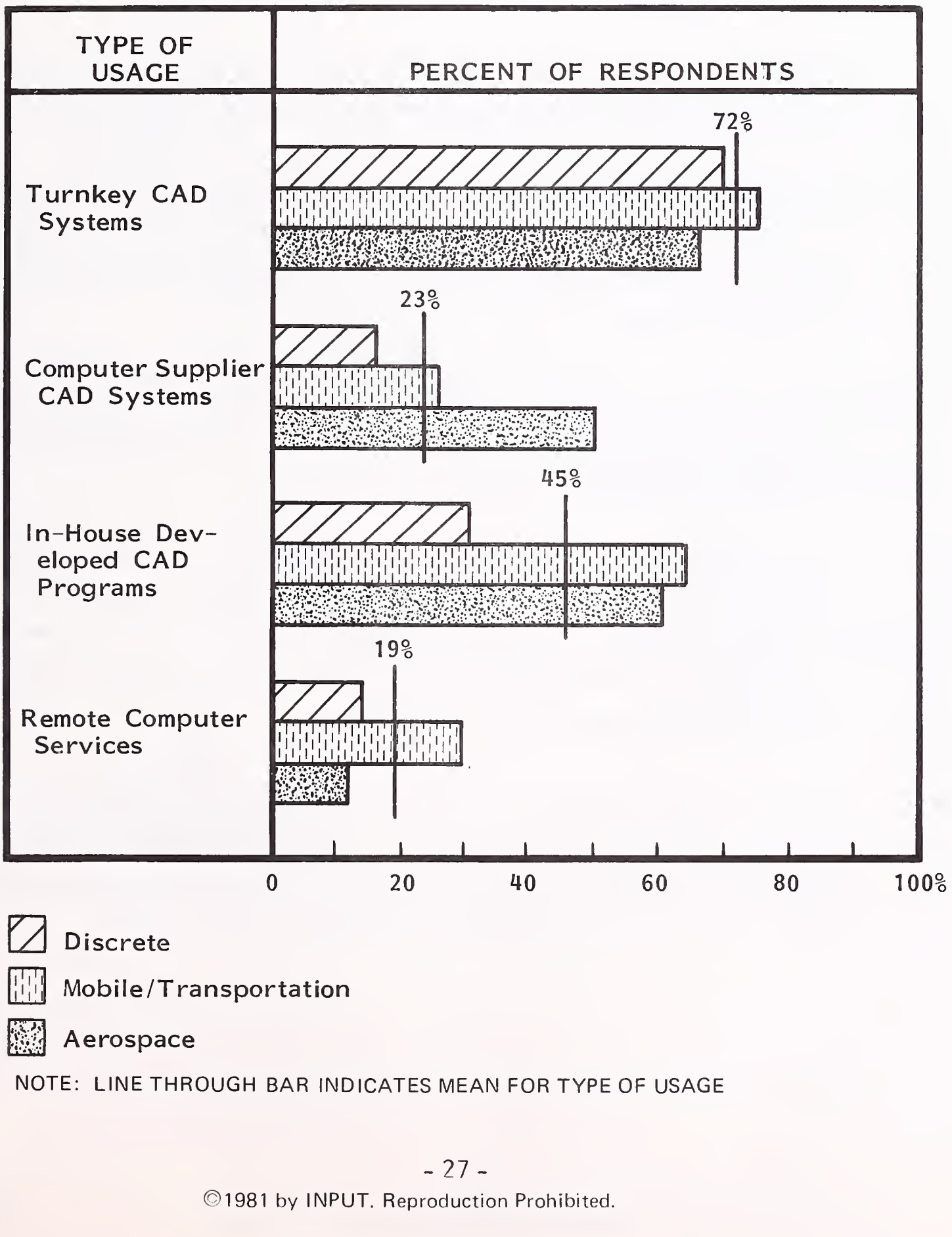
  - Discrete product manufacturers are depending more on turnkey CAD systems than are aerospace companies.

  - The use of computer supplier-based CAD systems is much higher in aerospace companies than in companies producing discrete or mobile/ transportation products.

  - In aerospace, in-house developed CAD systems with interactive design capabilities are in use. Some of these are being used with turnkey and computer supplier CAD systems.

EXHIBIT III-4

REPORTED CAD USAGE BY RESPONDENTS



NOTE: LINE THROUGH BAR INDICATES MEAN FOR TYPE OF USAGE

- General Motors' CADANCE and Northrup's N-CAD are examples of in-house developed, custom CAD systems used in mobile/transportation and aerospace applications.

- Differences in CAD usage probably result from a combination of product engineering needs and experience in using CAD. Aerospace companies are well established CAD users. They have strong needs for custom programs and for large CAD systems.

  - Heavy usage of CADAM in aerospace is not surprising since CADAM was originally developed by Lockheed for its aerospace applications.

  - The cost per terminal hour in aerospace applications is also expected to be higher than in discrete applications. This reflects the higher engineering content and the need for more sophisticated CAD for aerospace products.

- Exhibit III-5 shows the number of workstations reported at the interviewed user sites. This is generally the number reported at the corporate entity surveyed, usually a division.

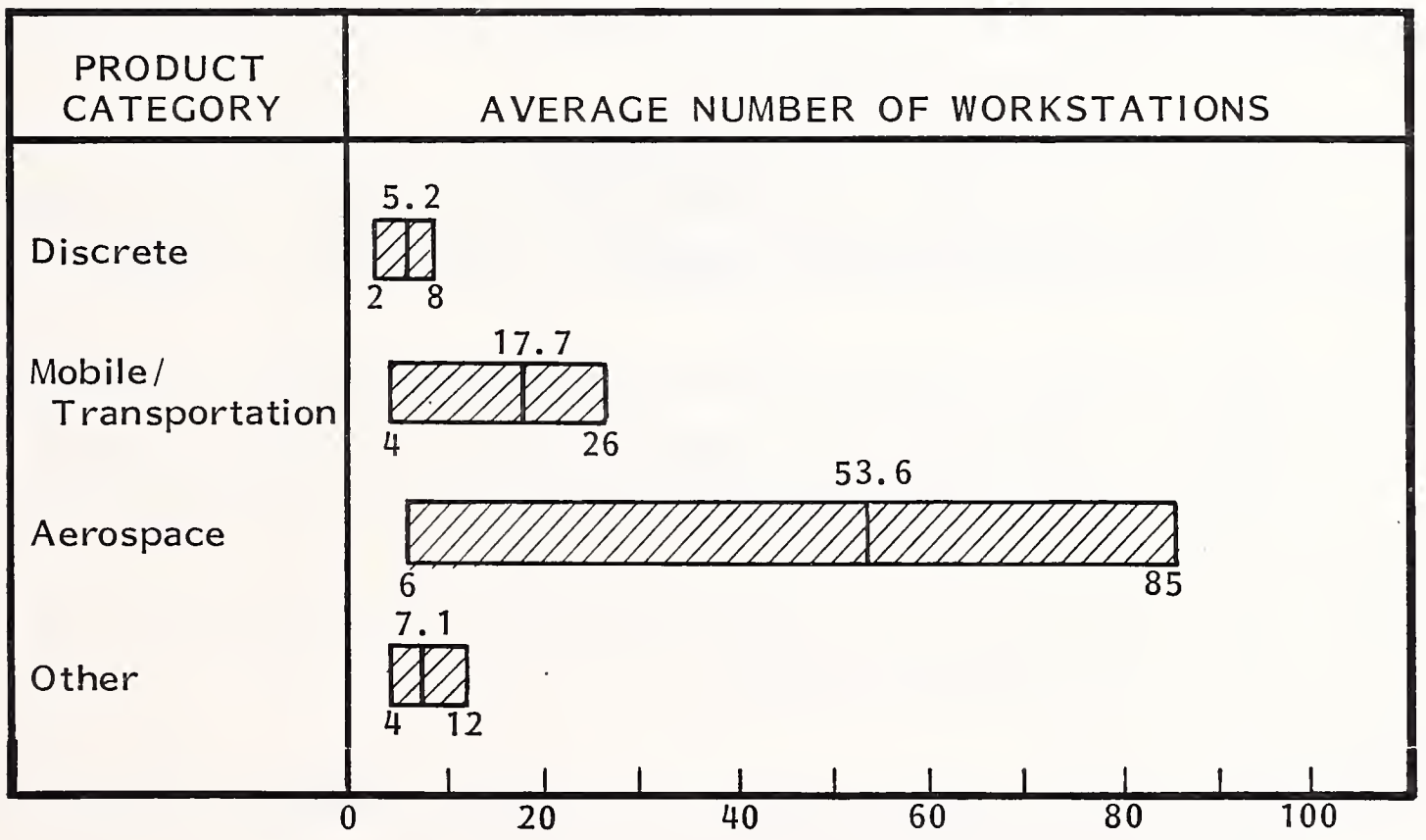
  - This exhibit also shows the strong differences between the user categories. Aerospace has large numbers of workstations installed.

  - The number of workstations at mobile/transportation company sites is intermediate between discrete and aerospace.

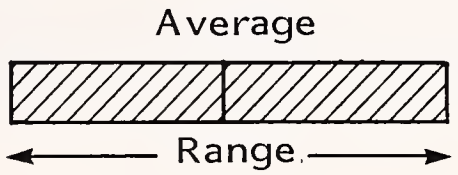
  - The much lower number of workstations at discrete product manufacturers indicates that this industry segment has a high potential for additional installations, even considering that these companies have fewer engineers and less complex products.

EXHIBIT III-5

NUMBER OF WORKSTATIONS PER USER SITE



Key:



NOTE: 10% of the highest and 10% of the lowest responses were eliminated from this exhibit.

- In many cases, the workstations reported here are being used on a two- or three-shift basis. Most companies have more users trained than workstations. One reported 600 trained users for 80 workstations.

3. CAD SYSTEMS USED BY RESPONDENTS

- Each organization reported the specific CAD systems they are currently using. These are tabulated in Exhibit III-6.

- Computervision, CADAM, and Applicon were the most frequently reported installations.

- Six organizations currently have more than one type of turnkey CAD system installed. Six other organizations have both turnkey and mainframe-based CAD installations (primarily CADAM).

- On a corporate basis, one large mobile/transportation product company reported installations of: Applicon, Auto-trol, Calma, CADAM, CADD, Computervision, Intergraph (M&S), and three in-house developed systems.

  - Exhibit III-6, and other tabulated results, present data on a divisional site basis where feasible.

- "Other" CAD systems reported used include in-house developed systems, CADD, CDC timesharing CAD services, and UNIVAC.

  - Japanese and European responses contain relatively more in the "other" groups than U.S. responses.

4. CAD SELECTION FACTORS

- A list of factors of importance to the selection of a CAD system were reviewed with the surveyed organizations. These organizations were asked to rate these factors in terms of impact on their system selection decision. The interviewees were also asked to provide additional important factors.

EXHIBIT III-6

RESPONDENTS' CAD SYSTEM INSTALLATIONS

TYPE OF CAD SYSTEM	USER PRODUCT CLASS				
	DISCRETE	MOBILE/ TRANSPOR-TATION	AEROSPACE	OTHER	TOTAL
Applicon	6	4	2	1	13
Auto-Trol	10	1	–	–	11
CADAM (IBM)	7	4	7	–	18
Calma	3	4	–	–	7
Computervision	7	4	9	4	24
Intergraph (M&S)	1	1	–	1	3
Others	6	4	4	1	15
Total	40	22	22	7	91

- The rating numbers supplied by the interviewees show considerable variation in average level and in spread. Since each individual's response "calibration" is different, Exhibit III-7 presents these results in a way that minimizes the calibration differences and shows those factors which are most (or least) important to the interviewee.

  - A factor was counted in the histogram's top or bottom row of Exhibit III-7 if it was the only factor with the "highest" (or "lowest") rating.

  - A factor was counted in the histogram's two middle rows if it was one of two factors given "high" (or "low") ratings compared to all other factors.

- "Software" and "system flexibility" are the factors rated as most important to CAD selection.

  - The definition of "software" leaves room for much individual interpretation. It was generally taken to mean the application-oriented software capabilities.

  - "System flexibility" indicates that these CAD users want systems which are general purpose and not optimized for just one task.

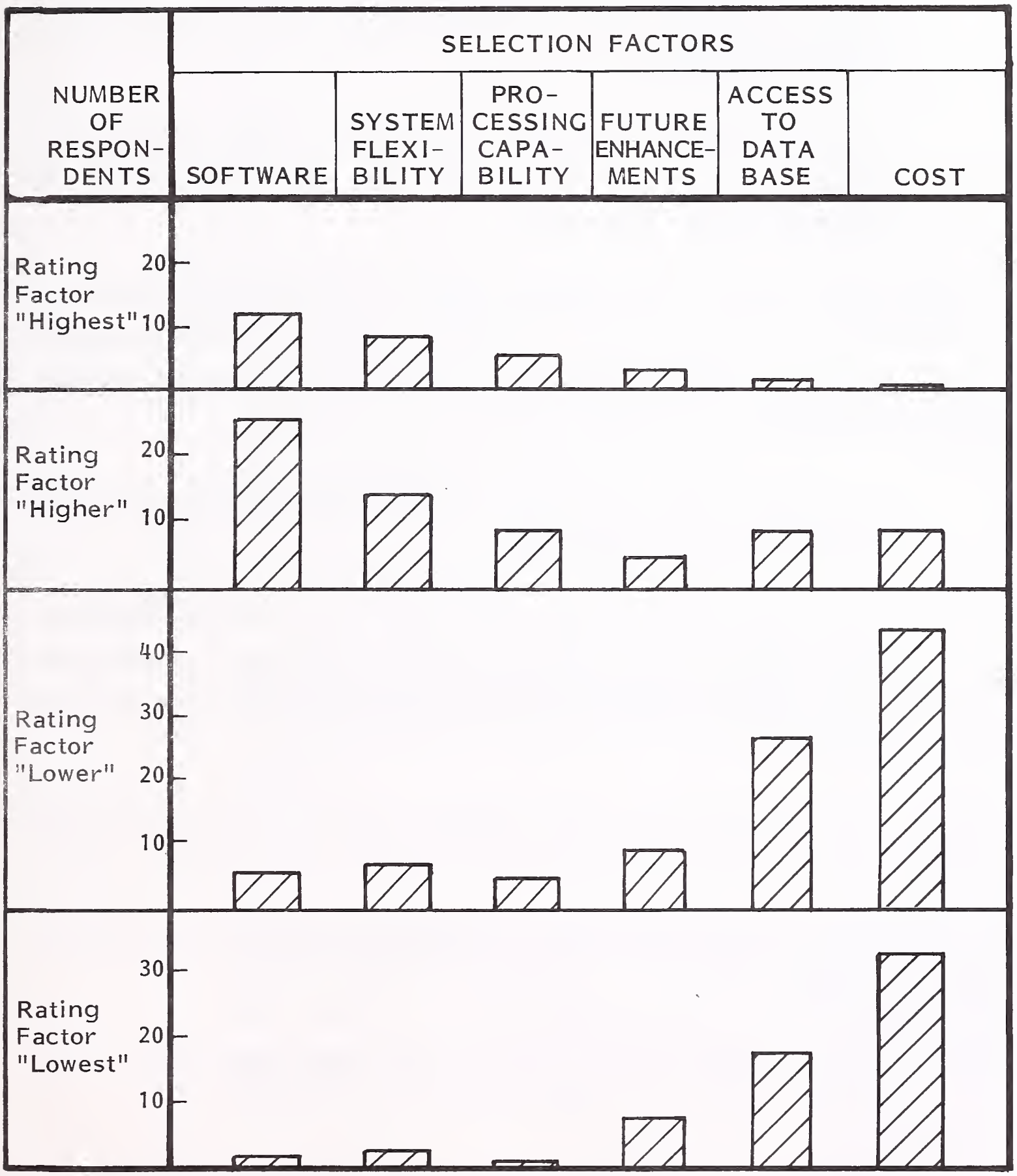
- "Processing capability" and "future enhancements" were generally not singled out as the most (or least) important factors. It is moderately surprising that "processing capability" is not at the top of the list. Many of the current CAD systems suffer severe degradation in performance under moderate loading and with background tasks running.

- The response on "future enhancements" indicates that, while these are important, the organizations using these systems are more interested in "in-hand" capabilities.

- "Access to data base" was rated as the next to least important factor.

EXHIBIT III-7

RESPONDENTS' RATING OF CAD SELECTION FACTORS



- The reasoning behind this response is not clear. CAD systems vary much in the time response in accessing a data base of drawing files.

- Current CAD systems also do not provide a data base which is organized to support the relationships between the elements of engineering information.

- It may be that in answering this question, users knowledgeably discounted the limitations of current CAD systems in providing an integrated CAD/CAM data base.

- "Cost" was by far the least important factor in CAD selection. Some users went so far as to rate "cost" as a 1, while other factors were rated in the 8 or 9 range. Many other users placed a wide gap between the importance of cost and other factors.

  - The message seems to be that if a CAD system has other important features, it can cost much more.

  - One of the mechanical users noted that cost was not an important factor because the cost differences between alternative systems were small. Another pointed out that ROI was the important factor, not cost per se.

- Many additional important system selection factors were listed by the interviewees.

  - Human factors, ease of learning, and user orientation were frequent listings.

  - One user stated that the demonstration of the CAD system was an important selection criterion.

  - Vendor support and maintenance were frequently listed as important.

- Compatibility with other systems, within a company, between divisions of a company, and with a customer's CAD system are added factors.

- The reputation, size, and stability of the CAD vendor were noted as important by several users.

- Networking and communication to a host were also listed as important factors.

5. CAD BENEFITS

- The organizations surveyed were also asked to rate the importance of benefits they have realized with CAD.

  - These data have been analyzed using the same "highest" (or "lowest") and "high" (or "low") technique used to analyze CAD selection factors, as shown in Exhibit III-7.

- Cost savings, the first column of Exhibit III-8, was by far the highest rated benefit.

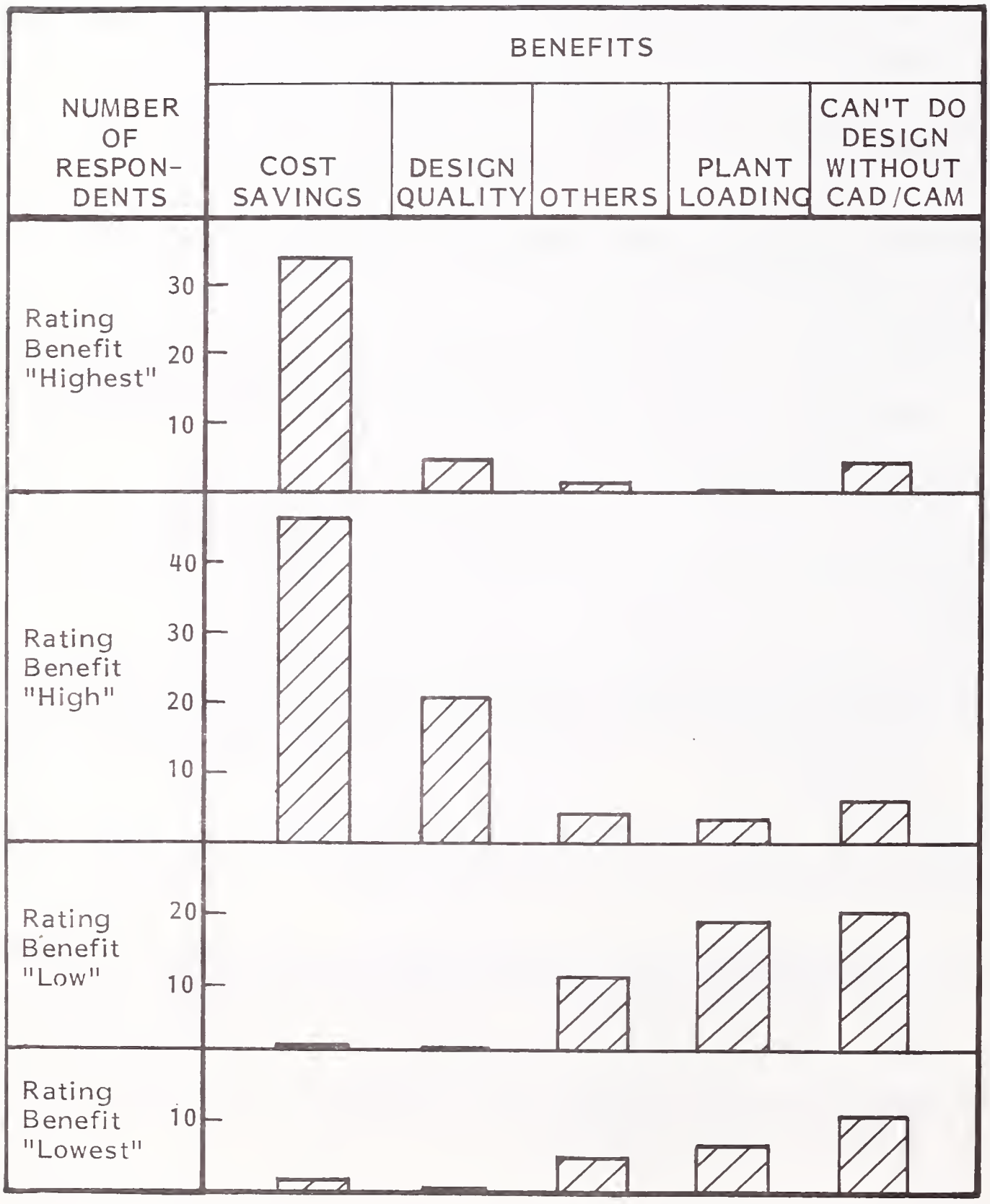
  - These CAD systems are predominantly being used for drafting tasks; therefore, productivity improvement is interpreted as reducing drafting man-hours.

- Improved design quality is the second highest benefit.

  - A recommendation for further research is to determine how this improved quality is achieved. In a narrow sense it may result from more consistent, improved documentation. In a much broader sense it may be the result of more intensive design with more consideration of alternative design approaches.

EXHIBIT III-8

BENEFITS OF CAD (PRESENT SYSTEMS)
AS SEEN BY RESPONDENTS



- Other factors, which include manufacturing efficiency, employee morale, and better product maintainability, were given comparatively low ratings. Achieving better plant loading was the second to lowest factor.

- The lowest factor was the benefit of doing a design with CAD that cannot be done without it.

  - There are exceptions to this. Three organizations rated it as the highest benefit, while seven gave it a "high" rating.

  - Most organizations, however, are not doing tasks with CAD that cannot be done manually.

6. SATISFACTION WITH PRESENT CAD SYSTEM

- Two questions explored the satisfaction of the user organizations with their present CAD systems:

  - "Rate your present system in terms of it meeting your expectations."

  - "If you were to start over, would you buy from the same vendor?"

- The users were overwhelmingly satisfied with their present CAD installations. Exhibit III-9 shows that 65 out of 74 respondents to this question judged that their system equaled or exceeded their expectations.

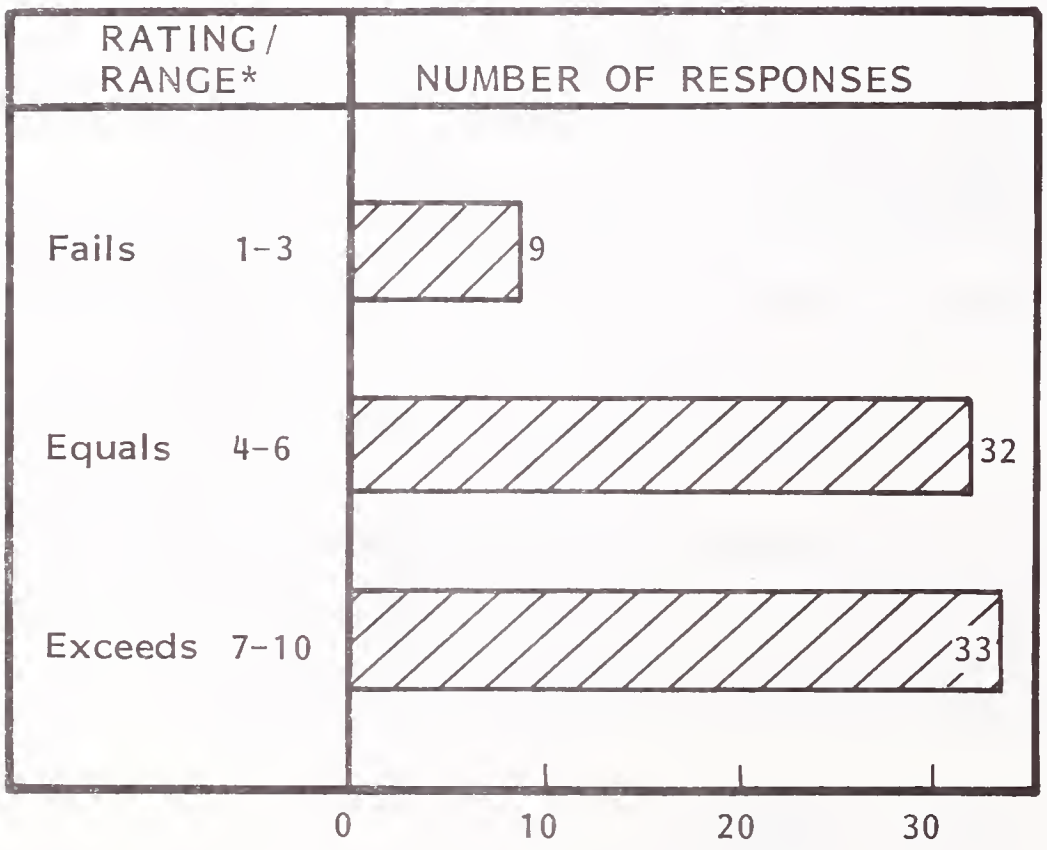
  - Of those who were not satisfied, several had custom developed systems and two were in Japan.

  - Some were not satisfied with the productivity of their system or believed that its costs were too high.

  - There was no significant difference in responses from the discrete, mobile, and aerospace product categories.

EXHIBIT III-9

RESPONDENTS' RATINGS OF CAD INSTALLATIONS
VERSUS EXPECTATIONS



*1 - Totally Fails to Meet Expectations
5 - Equals Expectations
10 - Far Exceeds Expectations

- The responses on buying from the same vendor again were strongly in favor of the present CAD vendors. As shown in Exhibit III-10, 54 of 73 responses were "yes."

  - The "other" category was made up of those who indicated that the door would be open to other vendors.

  - This question was considered in the past tense and may not be fully indicative of future procurements.

  - The reasons stated for a "no" or "other" answer included a need to have IGES, standardization on CAD systems within the company, and vendor changes to be compatible with suppliers and customers.

  - In Japan, the need to support Japanese drafting standards and to provide Kanji text was noted.

  - The need for a data base and to perform engineering functions other than drafting was noted.

- These responses are in keeping with the current marketing strategy and sales tactics of CAD vendors to establish an initial position in each company. Once established, the probability of the CAD vendor continuing to sell systems to that company is very high.

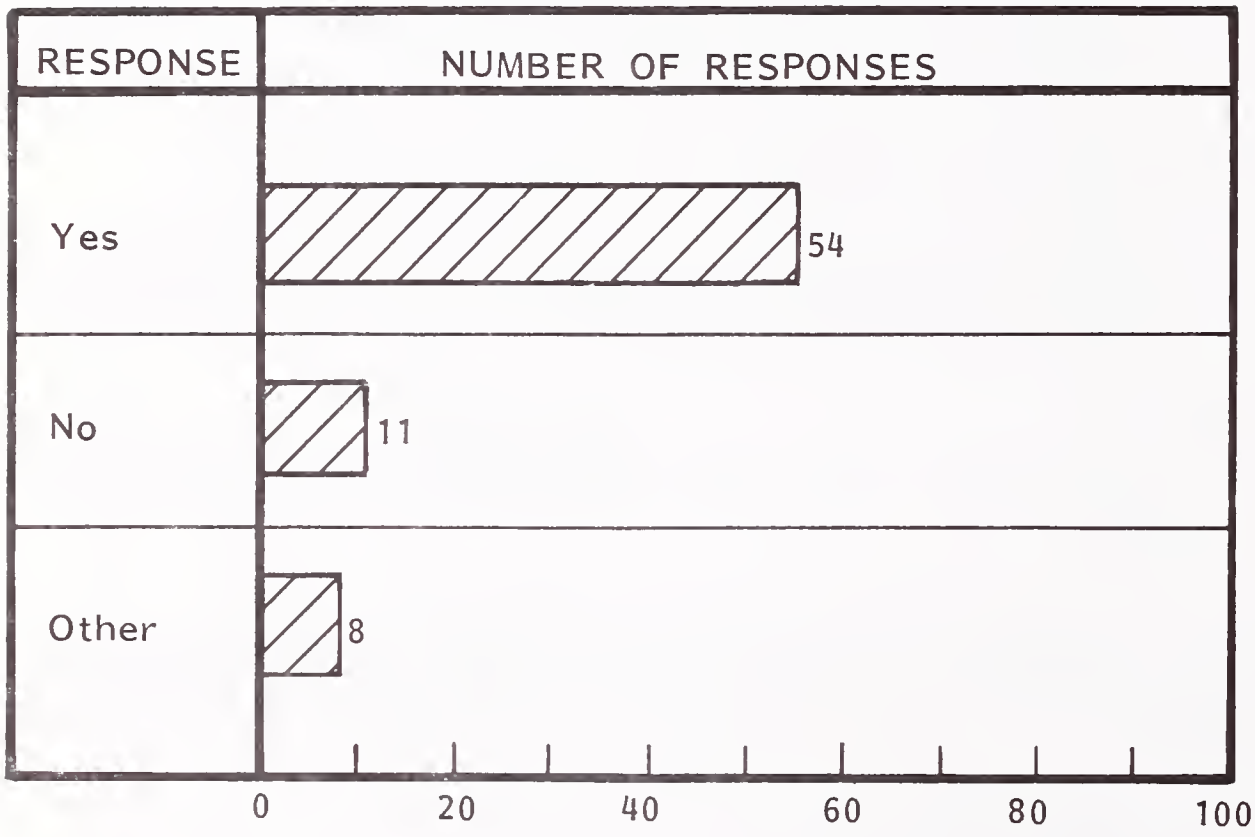
7. EXPANSION PLANS AND NEEDS

- The 76 interviewed organizations were asked to describe their plans to expand their CAD/CAM systems in the period 1981-1986. The results of this question are of interest, but statistical analysis is not useful because of individual variations in the answers.

- Almost all organizations plan to greatly expand their CAD systems in the next five years.

EXHIBIT III-10

RESPONDENTS' WILLINGNESS TO BUY FROM
THE SAME VENDOR AGAIN



- One exception was a company with a single station system that may eliminate CAD entirely. Management does not perceive it as profitable.

- Many large systems with 20 to 100 workstations will be expanded.

- A large fraction of the small installations of 1 to 10 workstations will more than double in size by 1986.

- There is a strong loyalty, perhaps necessitated by compatibility, where expansion is planned using in-place CAD vendors.

  . Some respondents stated that they would buy systems from other than their current vendor, if "compatible."

  . The realization of an IGES standard that is provided by most CAD vendors would open up the "locked-in" position of an on-site CAD vendor.

- CAD hardware plans include upgrading as well as expansion.

  - Some users plan to upgrade to color terminals and to buy workstations with more dynamic capabilities.

- Dynamic capabilities may be much more important for some applications.

  - There is considerable interest in acquiring intelligent workstations. Some users plan to use these at remote and small engineering sites that do not justify a complete CAD system.

  - Communications additions are planned (CVNET and others) to link CAD systems to mainframes and to each other.

- Several users plan to procure Computer Output to Microfilm (COM) equipment to produce microfilm output at high throughput.

  . Plotting is viewed as a major problem in degrading CAD system response, and as an output bottleneck.

- Major software purchases to expand CAD/CAM systems are planned by existing users.

  - Most software additions are planned to make the user's CAD system more integrated with all engineering and manufacturing functions.

    . More use of analysis software is planned, including better finite element mesh generators, programs to compute mass properties, and programs for analysis of articulation and kinematics.

    . NC capabilities and post-processors will be added to many CAD installations. Direct Numerical Control (DNC) is also planned by some users.

    . Nesting, family of parts, and other CAM software will be added and integrated with CAD by many users.

  - A few users indicated their plans to add solid modeling software.

- Some organizations indicated plans to acquire software/hardware which will better integrate their CAD into an engineering manufacturing data base. This includes provisions for design of assemblies, formal data base management systems (DBMS), and bill of material structured systems.

B. MECHANICAL DESIGN DEFINITION

- Design definition includes a group of functions where most CAD systems have minimal capabilities today, and where users have limited experience using CAD.

  - 3-D wire frame and mixtures of wire frames with bounded surface models can be generated with most turnkey CAD systems. These models are intended to be used to create part shape designs.

  - Layering techniques allow a mechanical designer to simultaneously work on different parts in an assembly. Checks for interference and fit require considerable interpretation and interaction by the CAD user-designer.

  - Engineering procedures and techniques to use these 3-D models and layering for the creation of a mechanical system layout are either not used or not well developed at most companies. Exceptions are in aerospace and automotive industries where the application of present CAD technology is further developed.

- A volumetric model (solid model) is a representation of the shape of a mechanical part or assembly which defines the geometry of a part completely. It is a complete definition of the shape, useful for most engineering applications without further human interpretation. Volumetric modeling in a CAD system allows the designer to interactively create and modify volumetric models.

- There are many volumetric modeling systems under research and development today. Each of these generally has different advantages and limitations. With a few exceptions, these volumetric modeling systems are only being used experimentally.

- There are more technically feasible capabilities, in addition to volumetric modeling, to extend the utility of CAD systems for mechanical design definition.

  - These extensions include support of relationships between a machine's components, and methods of searching for and incorporating standard parts into new designs.

1. TRUE 3-D GEOMETRY

- Users were asked to rate the importance of "true 3-D geometry" to their application now and in 1986. True 3-D geometry represents the available but not intensively used capability to create 3-D wire frame and surface models.

- Exhibit III-11 shows that mechanical users plan to make much more use of their system's 3-D capabilities in 1986 than now.

  - There is a large spread for both responses. For the 1986 response, 35 (of 70) users rated 3-D as a 10 (very important); these represented 25% of the discrete, 67% of the mobile/transportation, and 57% of the aerospace groups. In comparison, 18 respondents gave 3-D a 10 rating for present use.

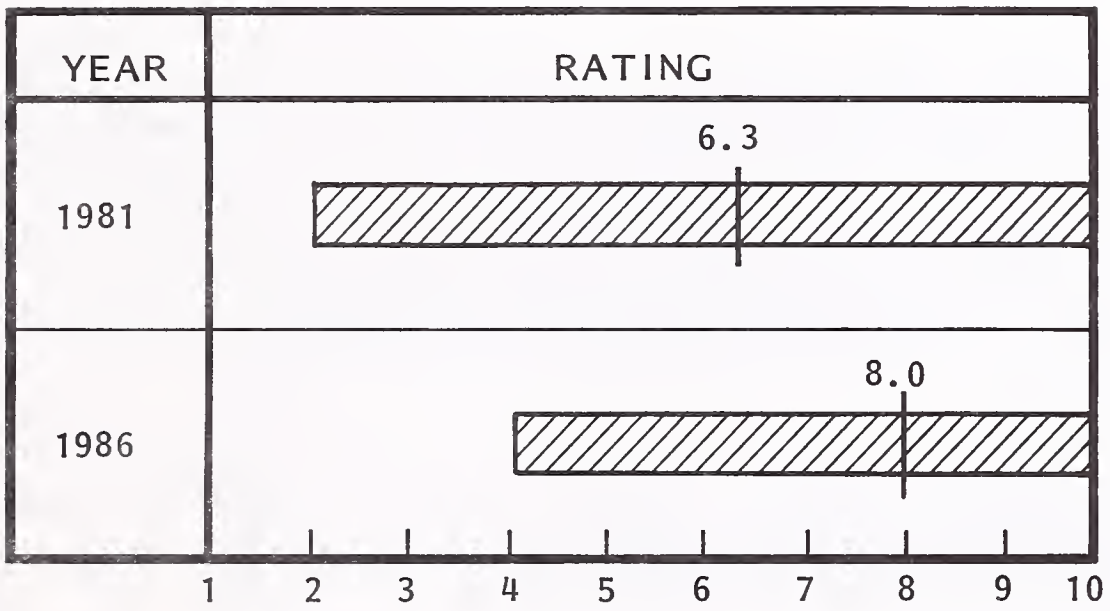
  - For some users, the 3-D capabilities are used only for restricted applications and not for all designs. Design of cams was given as an example of this.

2. DYNAMIC MOTION

- Dynamic motion capabilities may be provided by high performance calligraphic and raster scan displays. In advanced versions of these displays, such as the Megatek 7250 and the E&S PS300, the display's processor converts 3-D wire

EXHIBIT III-11

RESPONDENTS' RATINGS, IMPORTANCE OF 3-D GEOMETRY



Rating: 1 = Not Important, 10 = Very Important

NOTE: 10% of the highest and 10% of the lowest responses were eliminated from this exhibit.

frame representations, in real time, to the 2-D display projection. The operator may continuously change and control this projection using data tablets or dials.

- Exhibit III-12 shows that mechanical users' assessment of the importance of dynamic motion is increasing, but that they do not consider it as important as 3-D geometry.

  - For 1986, 12 users gave a rating of 10 to dynamic motion.

3. VOLUMETRIC MODELING

- Users were asked if they currently use volumetric modeling, and if they expect to be using volumetric modeling in their CAD/CAM installations by 1986.

  - The majority of responses, as tabulated in Exhibit III-13, show that mechanical users plan to use volumetric models in their CAD systems by 1986.

- There are several volumetric modeling systems available now which users reported are being used on an experimental or research basis.

  - GM Solid - under evaluation by several divisions of General Motors.

  - Calma Solid modeler.

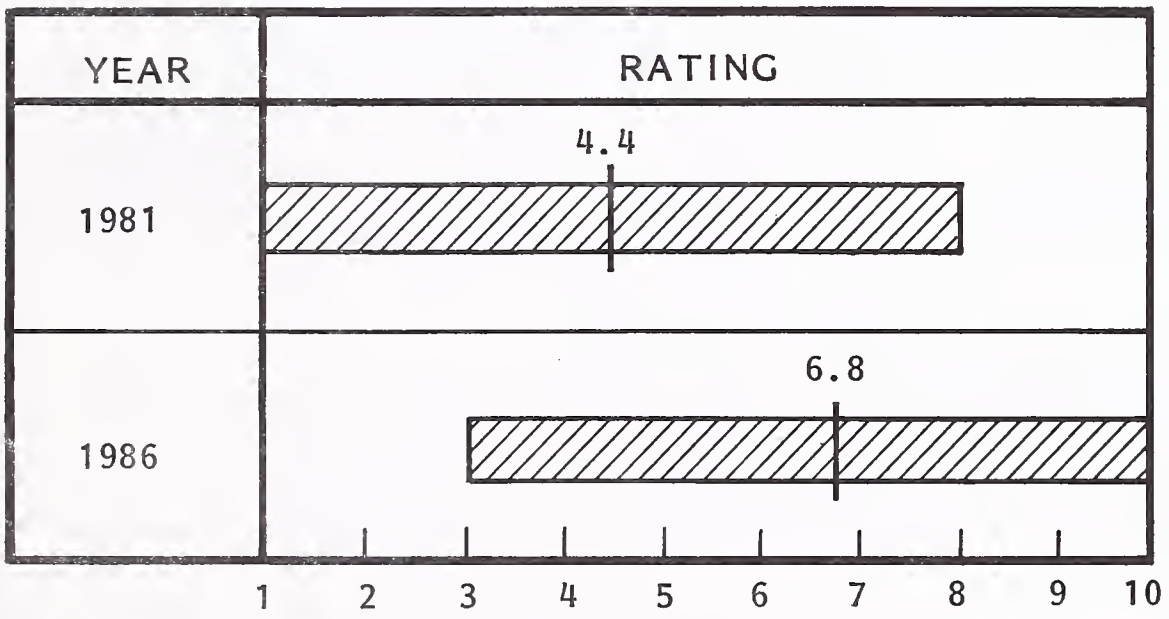
  - COMPAC - University of Berlin.

  - RPC (Rational Parametric Cubics) under evaluation by two aerospace companies.

  - PADL - University of Rochester.

EXHIBIT III-12

RESPONDENTS' RATINGS OF IMPORTANCE OF DYNAMIC MOTION



1 = Not Important, 10 = Very Important

NOTE: 10% of the highest and 10% of the lowest responses were eliminated from this exhibit.

EXHIBIT III-13

RESPONDENTS' CURRENT AND PROJECTED USE
OF VOLUMETRIC MODELING

PRODUCT CATEGORY	NUMBER OF RESPONSES		
	NOT NOW AND NOT IN 1986	NOT NOW BUT WILL IN 1986	USING NOW AND WILL IN 1986
Discrete	15	23	2
Mobile/Transportation	2	8	4
Aerospace	0	11	2
Other	1	5	1
All Respondents	18	47	9

- The percentage of users who are using and plan to use volumetric modeling is higher in the mobile/transportation and aerospace categories. The discrete product category has the lowest planned use of volumetric models, but even here the percentage who plan to use this in 1986 exceeds 60%, as shown in Exhibit III-14.

  - One respondent stated: "(Volumetric modeling is) going to be the (new) color phenomenon."

  - The users are not all positive on volumetric modeling however:

    . Two had questions on the designer's ability to create shapes with Boolean commands.

    . Several expressed reservations about the current capabilities of volumetric modelers in development.

    . One stated they will acquire and evaluate the Applicon solid modeler.

    . Several who said they have solid modeling now appear to be interpreting the term "volumetric modeling" as synonymous with "3-D modeling."

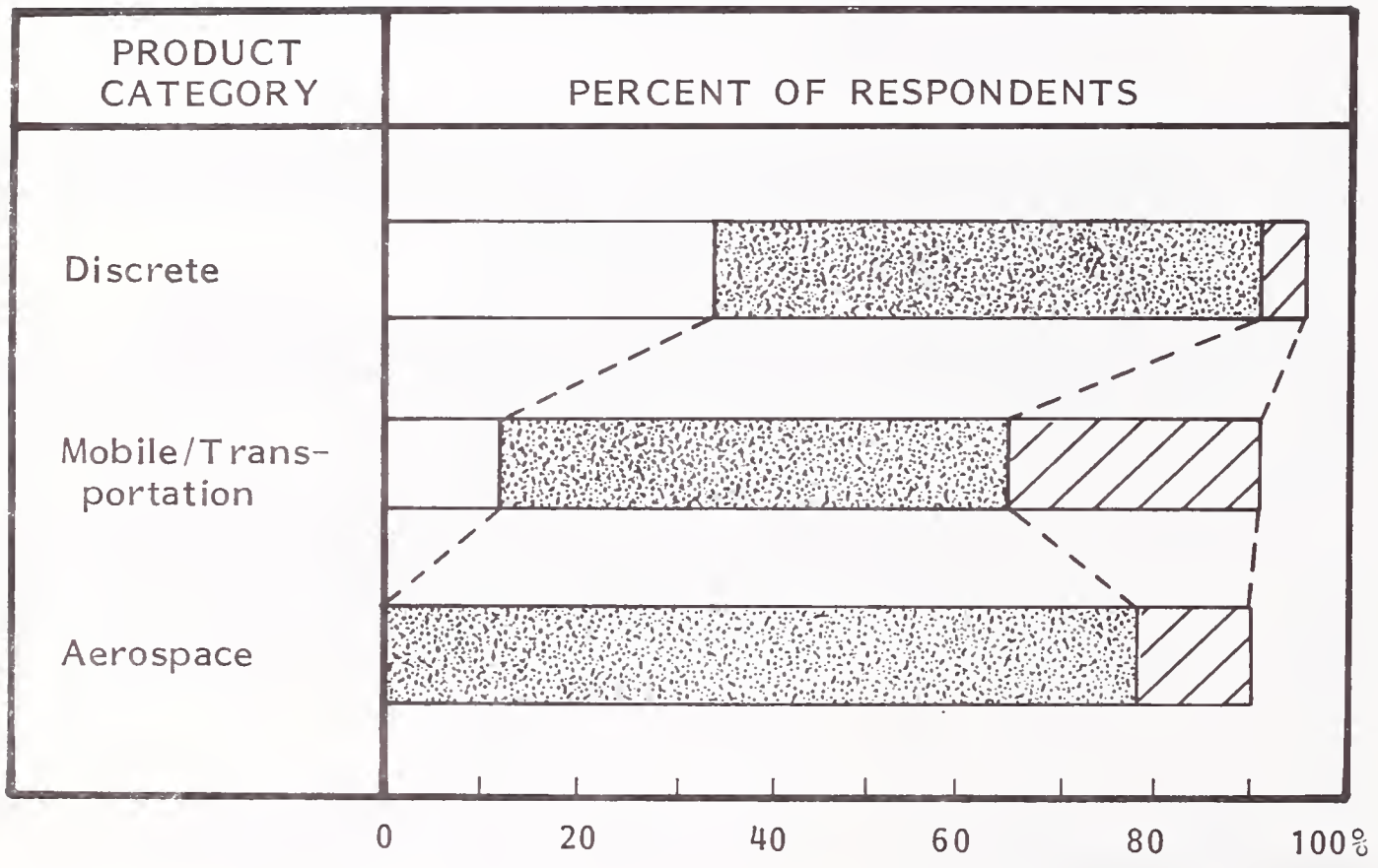
C. ENGINEERING ANALYSIS

- Engineering analysis includes many distinct procedures to determine if a design is adequate:

  - Structural analysis, which includes:

EXHIBIT III-14

VOLUMETRIC MODELING USE BY
PERCENT OF RESPONDENTS



  - Direct strength of materials analysis dealing with section and volume properties.

  - Finite element analysis (FEA), requiring finite element mesh models and extensive processing on larger computers.

- Thermal analysis which also includes direct analysis of heat transfer through material sections and finite element analysis.

  - Complex forms of thermal analysis may involve radiative and connective heat transfer as well.

- Analysis of mechanisms, which includes kinematics and kinetics.

  - Kinematics concerns the motions of a mechanism.

  - Kinetics (including dynamic forces) concerns the forces generated as a result of the motion.

- Analysis of assemblies for tolerance accumulation, interference, weight and balance, and other factors.

- Many other types of analyses, some which are specialized to a particular class of product.

- As a design is created, analysis is used to evaluate it and to modify the design to achieve product goals. This is a continuing process throughout the engineering of a product. If a CAD system is used at all stages, and for all tasks in this process, it is becoming an effective system for computer-aided engineering.

  - In most CAD installations today, CAD is mainly applied to the generation of drawings and to a lesser extent to design and analysis.

- Software systems for finite element analysis are extensively used today, but are not well integrated with turnkey CAD systems.

  . Finite element analysis programs typically require 32-bit or larger processors with large (or virtual) memories. These processors are usually separate from the turnkey CAD processor.

  . Most turnkey CAD systems offer finite element mesh generation (and post processing) capabilities, but these have serious limitations today.

  . CAD users are not as proficient in using the finite element mesh generation capabilities of their CAD systems as they are in using the system's drafting capabilities.

I. FINITE ELEMENT MODELING

- Users with mechanical engineering applications were asked to rate the importance of finite element modeling capabilities on their CAD/CAM systems now and in 1986. Exhibit III-15 shows the result of this rating.

  - The use of finite element modeling and analysis will increase substantially by 1986.

  - Twenty-three users rated FEM as essential in 1986.

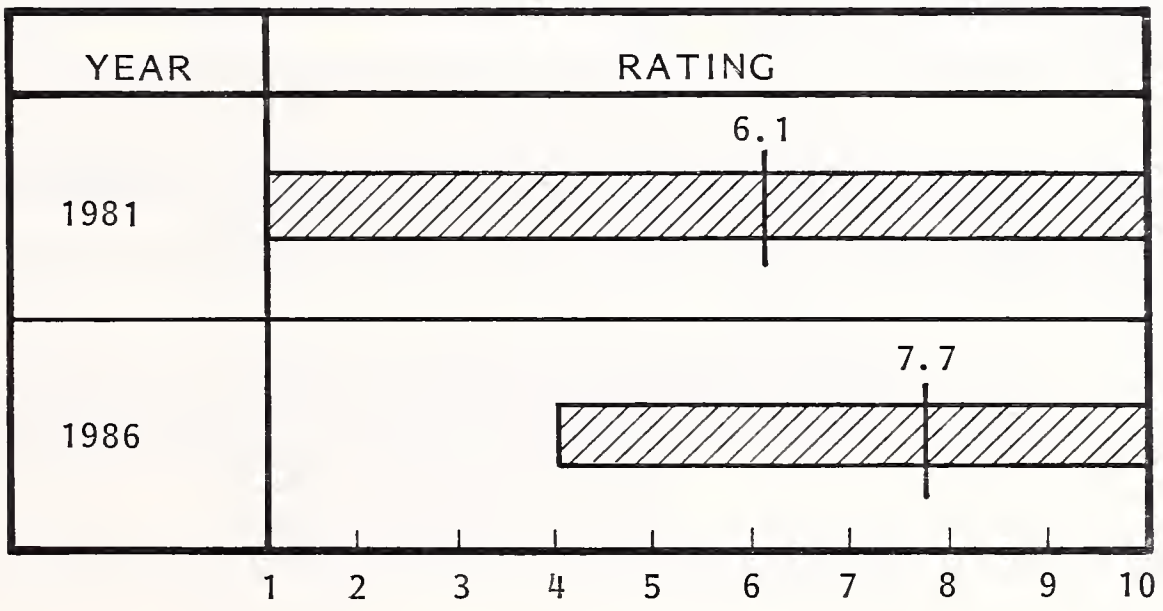
  - There is a large spread in ratings for finite element modeling in today's systems, ranging from 1 to 10 (for the middle 80% of samples).

    . Twelve organizations rated today's use of finite element modeling as a 10.

    . Most use of finite element modeling today is provided by systems and services separate from the CAD system.

EXHIBIT III-15

RESPONDENTS' RATINGS OF
IMPORTANCE OF FINITE ELEMENT MODELING



Rating: 1 = Not Important, 10 = Very Important

NOTE: 10% of the highest and 10% of the lowest responses were eliminated from this exhibit.

2. COMPUTER USE FOR ANALYSIS

- The types of computer systems used for analysis and other processing-intensive functions are tabulated in Exhibit III-16.

  - The use of the turnkey CAD's processor for analysis is higher than expected. Since the majority of the turnkey CAD systems installed at this time have 16-bit processors, the type of analysis performed on these systems is limited.

- The aerospace industry with extensive analysis requirements and experience using CAD/CAM is the largest user of in-house mainframes for analysis.

- The discrete product manufacturers with generally simpler analysis needs are the largest users of the turnkey CAD system processor for analysis.

  - It is expected that this pattern will change as further experience is gained by discrete product manufacturers in the use of CAD.

    . There are two offsetting factors involved in this pattern change:

      - More extensive use of sophisticated analysis (such as FEA requiring more "mainframe type" processing.

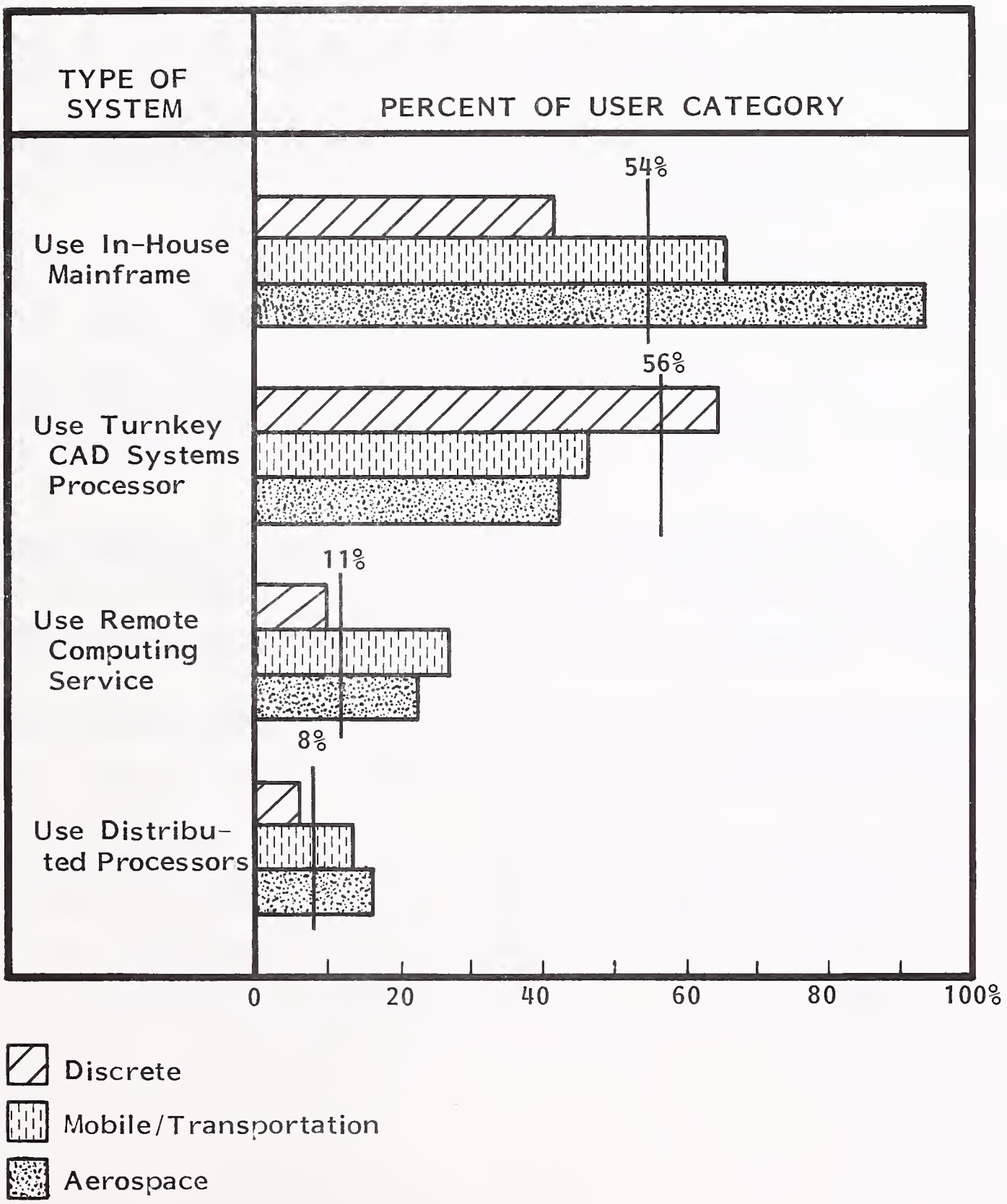
      - Increasing incorporation of so-called minicomputers such as the VAX into turnkey CAD systems.

- Remote computing is promoted today as being very cost-effective for processing-intensive applications such as analysis. It is surprising that comparatively little use of the services is reported, particularly by the discrete product manufacturers.

- Distributed processing is an advanced concept involving the use of the resources of multiple computers on a single job. Few respondents are using this

EXHIBIT III-16

COMPUTER USE FOR ANALYSIS BY RESPONDENTS



capability today; however, the interviews indicate a building interest in this type of processing.

3. REMOTE COMPUTING SERVICES AND SOFTWARE PACKAGES

- Exhibit III-17 lists the remote computing services (RCS) reported to be used by companies for mechanical applications.

  - NASTRAN is offered by many remote computing services.

  - A.O. Smith is an example of a company which is both a user and offers software products for mechanical analysis.

- The software packages in use are listed in Exhibit III-18. Some of these are the same packages also offered on remote computing services.

- Most of the reported RCS and software packages are for analysis. Some are for NC.

- There are many different remote computing services and independent software packages for engineering. None of these systems or packages appear to be leaders in this market, except possibly NASTRAN for finite element analysis.

- The objectives of CAD system vendors is to provide analysis and NC functions on an integrated basis within their CAD systems.

  - In the next three to five years, major changes in the structure of this market (for processing services and engineering software packages) are expected as a result of competition with, or assimilation into, CAD products.

EXHIBIT III-17

COMPANIES SUPPLYING REMOTE COMPUTING SERVICES AND PRODUCTS

COMPANY	PRODUCT
• A.O. Smith	- NASTRAN - CSMP (IBM) - IMP (Mechanism Analysis)
• Boeing Computer Services	
• CDC Cybernet	- Stardyne (FEA)
• McAuto	- NASTRAN - ANSYS (FEA)
• SDRC	- SUPERB (FEA) - NASTRAN (FEA)
• SIA (Europe)	- FEA Program
• Systems Associates	
• United computing Systems	
• University Computing	- NC - ANSYS (FEA) - NASTRAN (FEA)
• University of Wisconsin	- FEA Program

NOTE: (FEA) = FINITE ELEMENT ANALYSIS

EXHIBIT III-18

COMPANIES SUPPLYING INDEPENDENT
SOFTWARE PACKAGES AND PRODUCTS

COMPANY	PRODUCT
• A.O. Smith	- Magnetics
• IBM	- APT - Business Graphics - NGS (Surfaces) - Stress
• McAUTO	- UNIAPT (NC)
• MSC	- NASTRAN (FEA)
• SDRC	- Supertab - Spice-2
• Swanson Associates	- ANSYS
• PAFEC	
• University of Michigan	- MSAP
• University of Miami	- Supersceptre

D. DOCUMENTATION

- Documentation includes the generation of engineering drawings, bill of material listings, illustrations for manuals and proposals, and other items needed to manufacture, install, support, and use a product.

- The predominant use of installed CAD systems today is to generate engineering drawings.

  - CAD systems have been used intensively for this function since the mid-1970s and are well developed to provide the operations needed by a draftsman.

  - Drafting productivity is one of the main competitive issues between CAD vendors.

1. RESPONSE TIME

- The response time of a CAD system is, at least, a multi-model function.

  - When a drawing has been recalled from the data base and is being modified, responses in the order of one second or less are encountered (if the system is not overloaded).

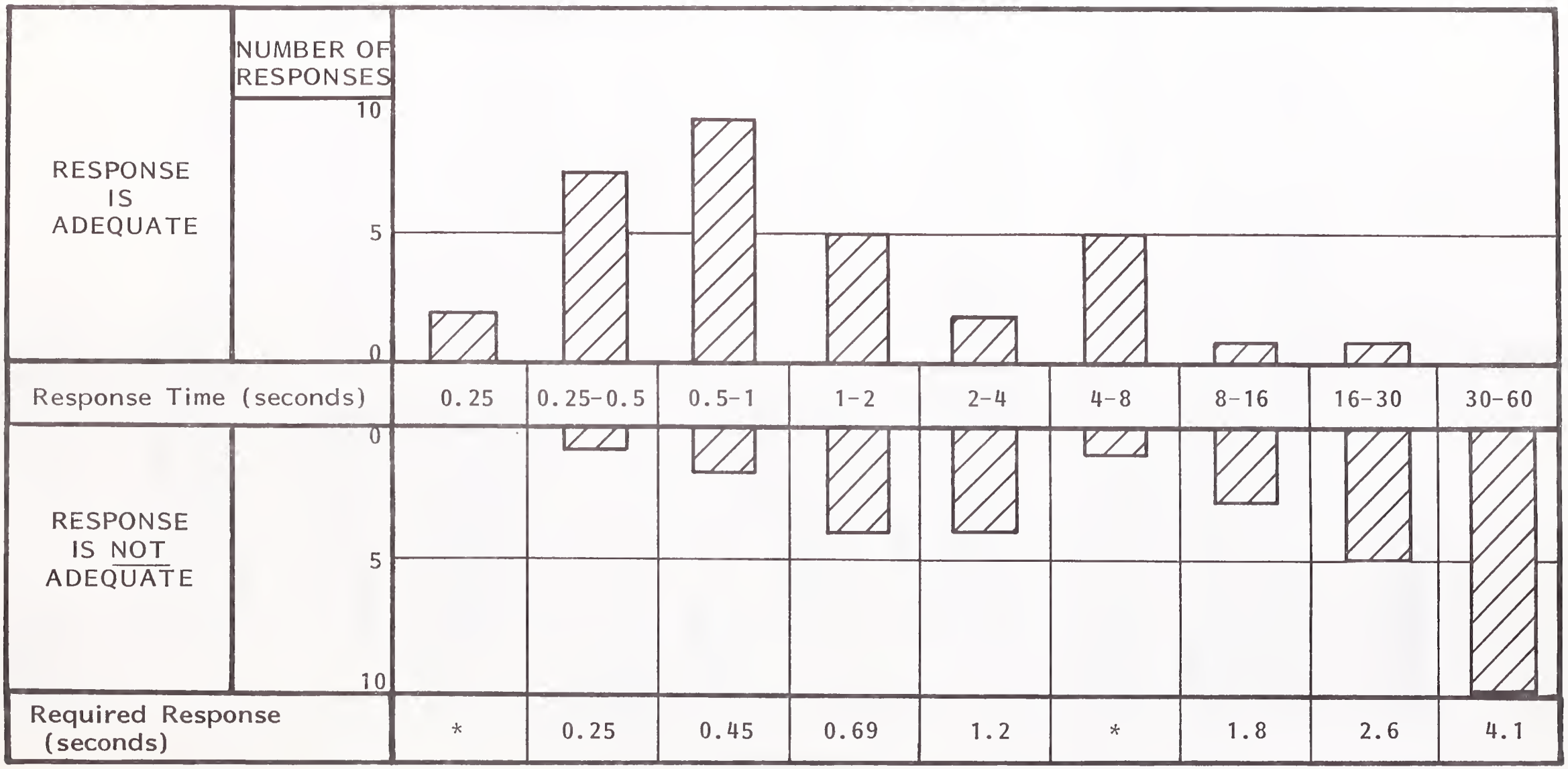
  - Recalling the drawing from the data base and building the working model (or display file) may run from tens of seconds to minutes.

  - Performing an analysis function, a surface intersection, or other function which requires substantial computing may require minutes or longer on current systems.

- The user's evaluation of adequate response time, plotted in Exhibit III-19, reflects this multi-model situation.

EXHIBIT III-19

USER EVALUATION OF RESPONSE TIME



*NO RESPONSE

- About half of the 62 responses to this question reported response times of 2 seconds or less.

- About half of the users considered their system's response as inadequate.

- At a response of 2 seconds, the user's satisfaction begins to turn to dissatisfaction. In the 1 to 2 second range, four of nine consider the response inadequate; and in the 2 to 4 second range, four of six consider it inadequate.

- The average of the "required response time" given by those not satisfied with observed responses of the CAD system, in each range, is given in the bottom row of Exhibit III-19.

- Users who were not satisfied with observed responses of less than 4 seconds generally stated that they require responses of less than 1 second.

- In the range above 4 seconds, the users seem to be generally addressing the response of the CAD system to commands that require substantial computing. Dissatisfaction with these response times begins above 8 seconds.

  - There is a wider ratio between the observed responses and the "required" response times in this range.

  - Some users "require" that a CAD system perform instantly (less than 1 second) to any command.

    . Computing power and software capabilities will increase, but the complexity of tasks undertaken in response to commands will increase. It appears unlikely that long responses will go away.

- Some CAD users reported using a statistics package which tabulates responses for different classes of commands.

  - Increased availability and use of this type of package is expected.

- Wider use of a statistics package will allow more objective comparison of CAD performance in operational environments.

- CAD user groups may provide the mechanism to report and compare this data.

- System loading is one of the most important factors affecting response time. Several users noted that overloading on their system accounted for the poor response times reported.

  - In comparing performance versus cost of CAD systems, the loading should be considered. Some systems which provide adequate response under light load will degrade faster when loaded.

  - Providing adequate computing power, memory, and on-line disk storage is a responsibility of the CAD user. Performance is degraded in some installations to the point where a moderate capital investment to expand the system would provide much more acceptable performance.

2. TIME TO TRAIN CAD USERS

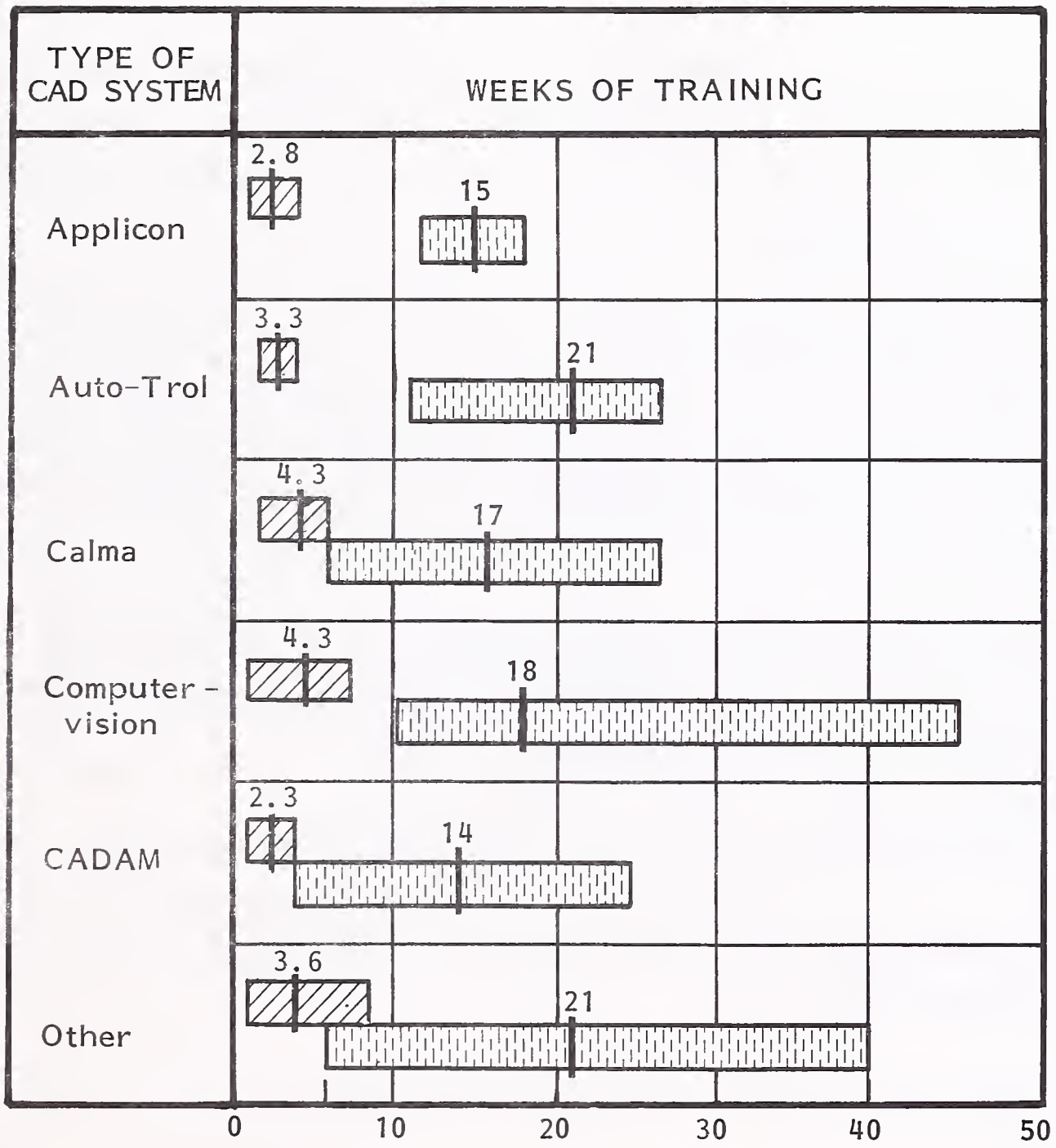
- Each of the companies using CAD for mechanical applications was asked to estimate the time it takes to train new operators to initially use the CAD system, and to gain complete proficiency. Exhibit III-20 summarizes these estimates for the most frequently reported CAD systems and for all others.

- Initial training ranged from one to seven weeks (80% of responses) and averaged three to four weeks.

  - This training usually is of a formal nature, provided by the CAD vendor, or by the company using materials provided by the CAD vendor. In a few instances, the using company may develop the course to meet its needs.

EXHIBIT III-20

TIME REQUIRED TO TRAIN CAD USERS, AS REPORTED BY RESPONDENTS



NOTE: 10% of the highest and 10% of the lowest responses were eliminated from this exhibit.

- The time to reach full proficiency is uniformly five to ten times longer than the initial training period. This period ranged from 4 to 45 weeks and averaged slightly less than 20 weeks overall.

  - This training is primarily on-the-job training (OJT), or the accumulation of experience by a CAD operator performing drafting.

  - There is high demand for draftsmen who are skilled CAD operators. In some industries and locations there is also high turnover. Shortening this long period to reach full proficiency would provide high payoff to the using company.

3. CAD LOCATIONS AND OPERATORS

- The CAD system was located in a central design and drafting facility in 58% of the companies. In 29%, terminals were co-located with the design groups. A mix of both approaches was reported by 13% of the users.

- Special operators of CAD systems are intensively trained and spend full time on the CAD terminal. Design engineers and draftsmen use the CAD system as a tool for performing their normal job.

  - Specialists operated the CAD system in 35% of the organizations.

  - Engineers and draftsmen operated the CAD system in 38% of the organizations.

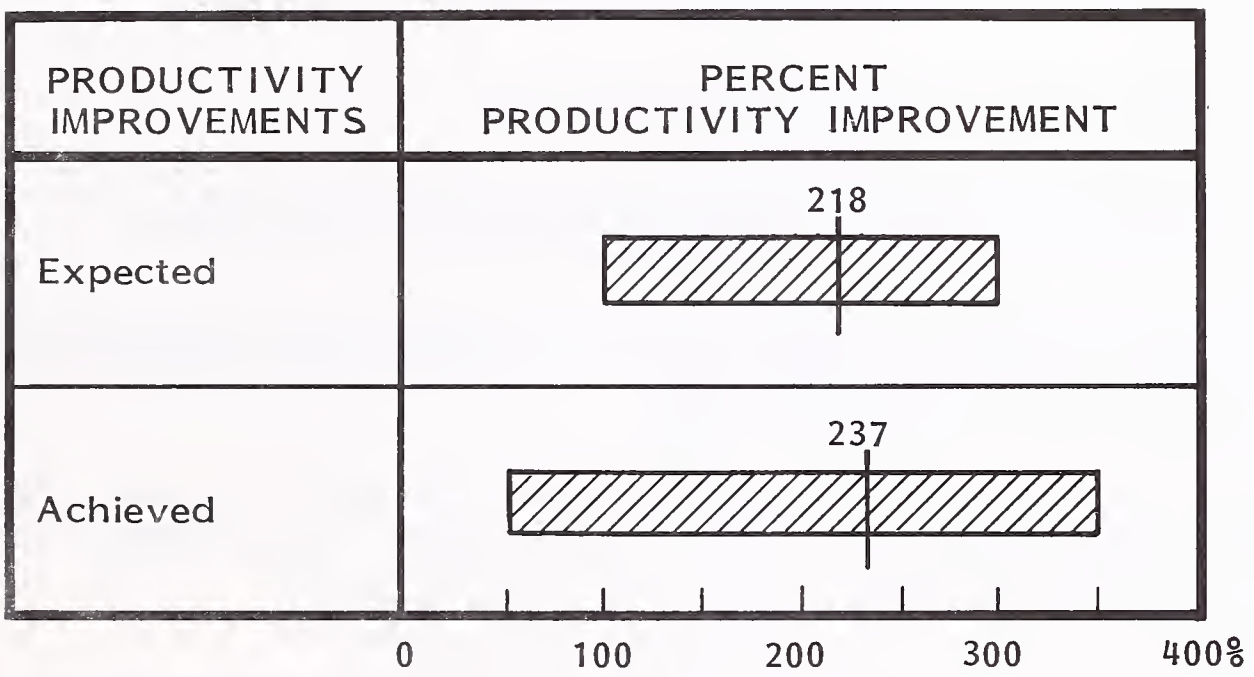
  - Both were operators in 24% of the organizations.

4. PRODUCTIVITY IMPROVEMENT

- The average achieved productivity gains, over manual drafting and design, are about as the CAD users expected. Exhibit III-21 shows an average expected gain of 218% and an achieved gain of 237%.

EXHIBIT III-21

PRODUCTIVITY IMPROVEMENT
REPORTED BY RESPONDENTS



NOTE: 10% of the highest and 10% of the lowest responses were eliminated from this exhibit.

- A majority of the users stated that their actual gain was less than expected, as shown in Exhibit III-22. These were offset by a few users who reported very large actual gains (greater than 1000%) and caused the average achieved improvement in productivity to be higher than expected.

- The mechanical users were also asked what productivity gain has been associated with engineering tasks.

  - Drafting - rated as the first or second most improved by 77% of the users.

  - Design - first or second by 38% of the users.

  - NC - first or second by 23% of the users.

  - Engineering analysis - first or second by 21% of the users.

- Many users measure productivity by comparing man-hours expended per drawing with CAD and without CAD.

- Several users reported that their achieved productivity increase was still growing as they learned to use their CAD systems better.

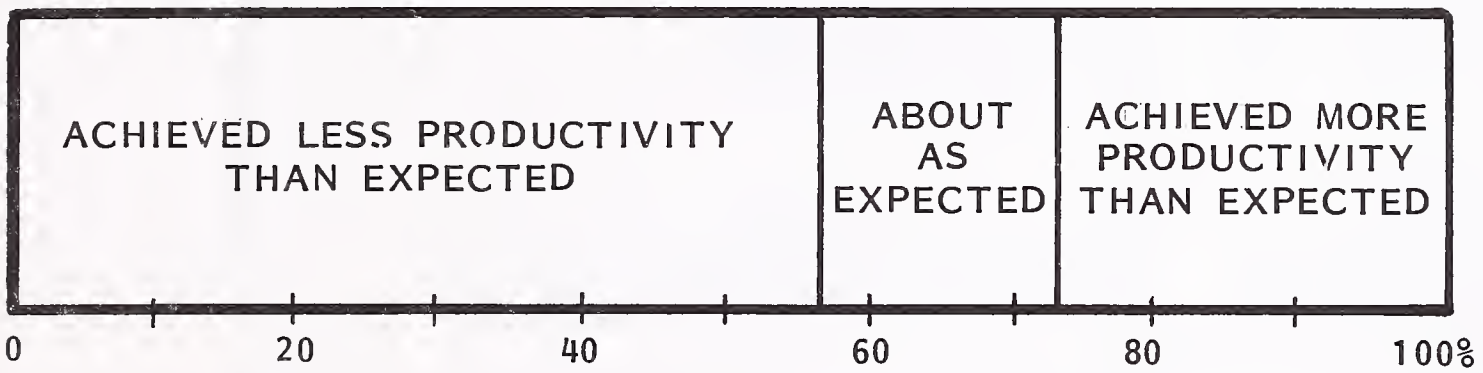
- One large user in the mobile/transportation category reported about equal productivity increases using turnkey CAD installations, CADAM, and its internally developed system. However, these systems are used for different applications.

5. FUTURE OF CONVENTIONAL DRAWINGS

- The users were asked how likely it is that CAD/CAM systems will render conventional manufacturing drawing obsolete. The results for 72 users are shown in Exhibit III-23.

EXHIBIT III-22

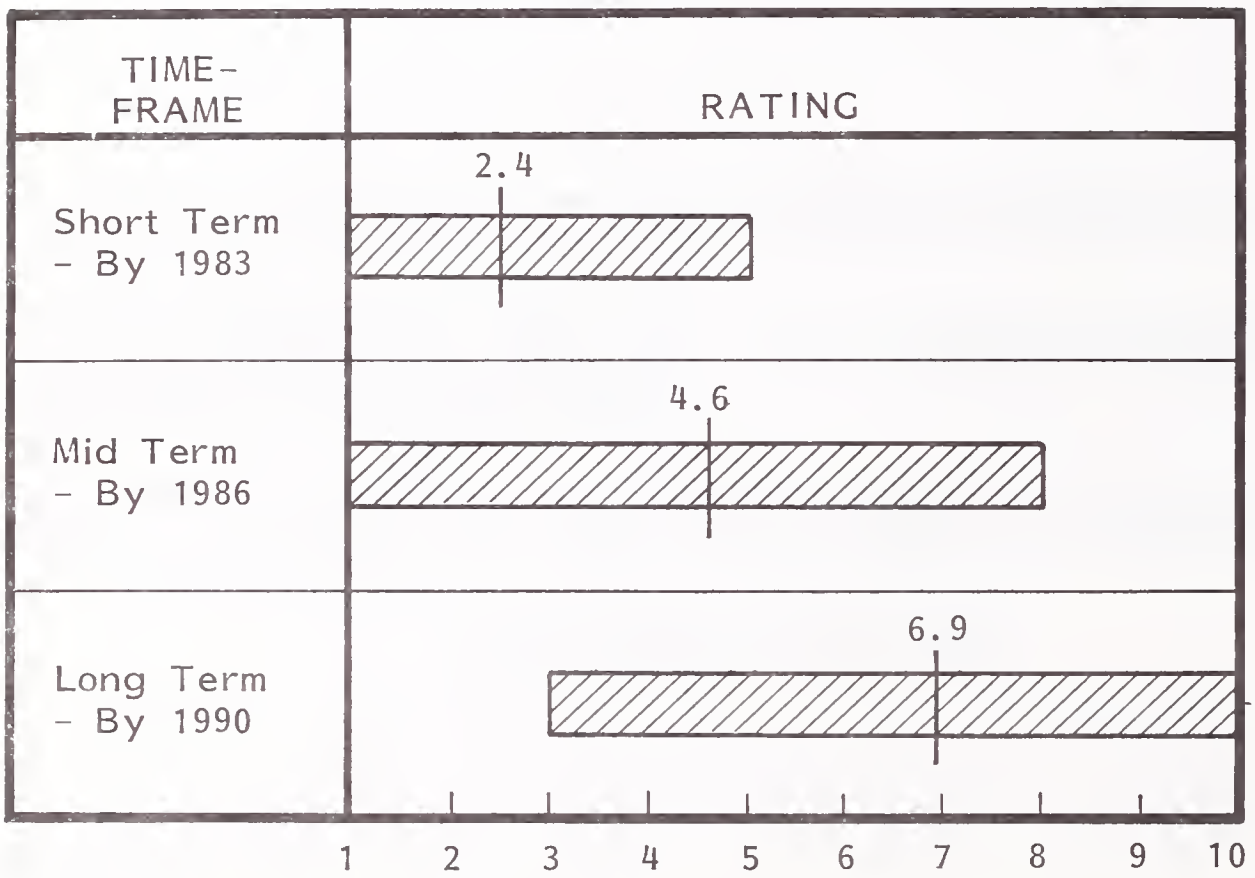
RESPONDENTS' ACTUAL PRODUCTIVITY
IMPROVEMENT VERSUS EXPECTATIONS



(Percent of Respondents)

EXHIBIT III-23

RESPONDENTS' RATINGS, PROBABILITY OF
CONVENTIONAL DRAWING MEDIA OBSOLESCENCE



Rating: 1 = Impossible, 5 = 50/50 Chance, 10 = Certainty

NOTE: 10% of the highest and 10% of the lowest responses were eliminated from this exhibit.

- By 1983, little change over present use of drawings is forecast.

- By 1985, most users give CAD/CAM a 50/50 chance of replacing conventional drawings with computer data files.

- By 1990, the survey expects major replacement of conventional drawings with CAD/CAM files. Nine respondents expect with certainty that conventional drawings will be replaced.

- There were many individual responses of interest regarding this question.

  - Many users indicated that their response pertained to most drawings, not all drawings.

  - There will be a continuing need for drawing at remote locations and because of legal requirements.

  - One respondent stated: "I would love to see it happen tomorrow."

  - Several of the users think their company (or organization) is far ahead of the industry in going away from drawings.

  - There will be a continuing need for microfilm (produced by COM) as a backup.

  - Communication with the user's suppliers is a problem which will slow the trend away from drawings.

    . Some respondents indicated that they could work without conventional drawings internal to their company, but their suppliers could not accept digital CAD data or NC tapes directly.

. IGES is needed to provide this communication in a digital form to suppliers.

- One respondent likened CAD to word processors. Word processors have not eliminated paper but have enabled better manipulation of what goes onto paper. This respondent expects CAD to have a similar relationship to engineering drawings.

- In reviewing this report, a member of the INPUT university panel expressed the opinion that drawings will always be around, but that conventional archival drawings will be phased out. The drawings used then will typically be "quick look" products produced on request and discarded after use.

E. MANUFACTURING ENGINEERING

- Manufacturing engineering includes those manufacturing tasks which are related to new products. These tools include:

  - Generation of process plans.

  - NC programming.

  - Design of tools and fixtures.

  - Plant rearrangement.

  - Changes in data collection.

- Group technology provides a methodology for manufacturing engineers to access what has been done before for similar parts, and to generate new manufacturing plans which are of higher quality, more consistent, and improve on the previous plans.

  - Provisions of group technology functions in CAD/CAM systems will become increasingly important, as shown in Exhibit III-24.

- The users' ratings of the importance of NC received one of the strongest responses. Exhibit III-25 shows that the present rating of NC functions as part of a CAD/CAM system averaged 6.8. Of the 74 responses, 19 rated NC as absolutely vital today.

- For 1986, the average rating for NC increased to 8.8, the highest for any CAD/CAM task. About half of the respondents (36) rated NC as absolutely vital to their CAD/CAM system in 1986.

- NC is now often used as a separate hardware or software system with an interface with the CAD system (such as services from MDSI's COMPACT II and APT programs on an in-house mainframe or remote computing service). Further research should determine more of the users' needs in this area.

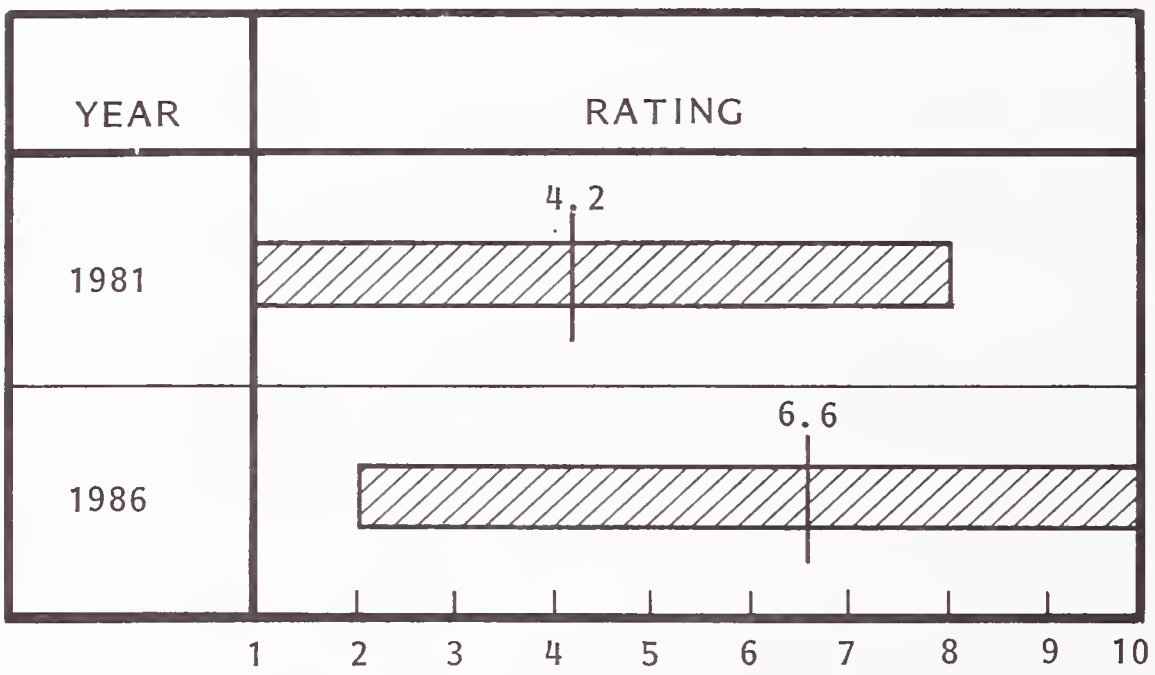
- The essential need for material requirements planning (MRP) as a function of CAD/CAM was not seen strongly by the mechanical users. These results are shown in Exhibit III-26.

  - The architectural, building, and construction industry users of CAD/CAM systems placed a much higher importance on MRP, both in 1981 and 1986.

- The MRP function is concerned with forecasting and scheduling manufacturing capacity, based on inputs from several sources, of which engineering is one.

EXHIBIT III-24

RESPONDENTS' RATINGS,
ESSENTIALITY OF GROUP TECHNOLOGY

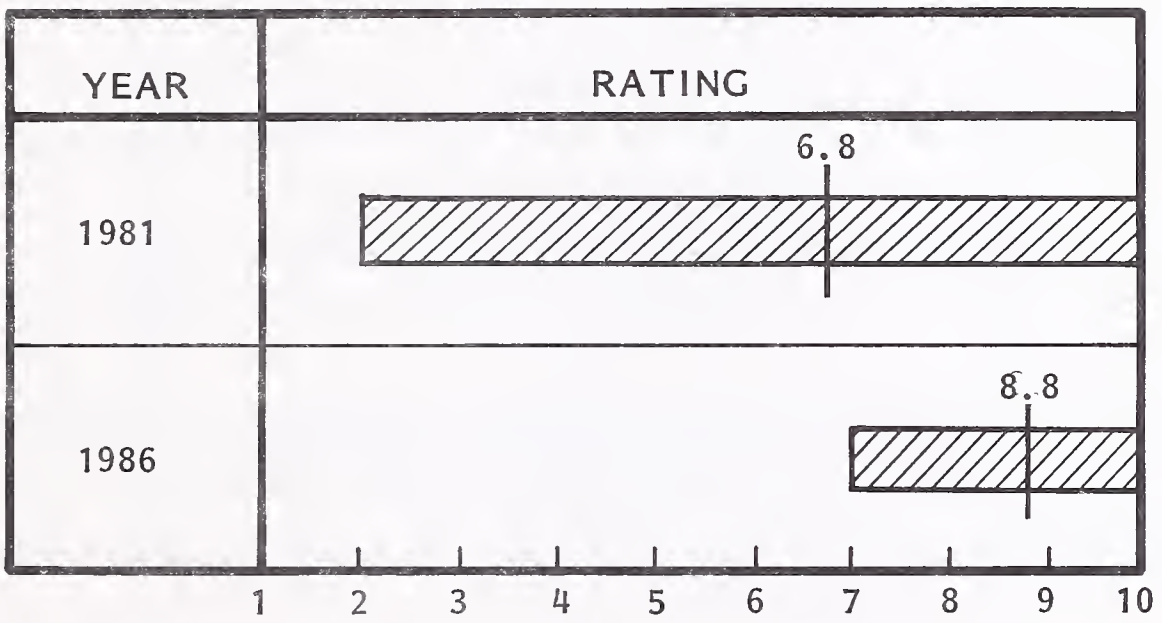


Rating: 1 = Not Essential, 10 = Very Essential

NOTE: 10% of the highest and 10% of the lowest responses were eliminated from this exhibit.

EXHIBIT III-25

RESPONDENTS' RATINGS,
ESSENTIALITY OF NC

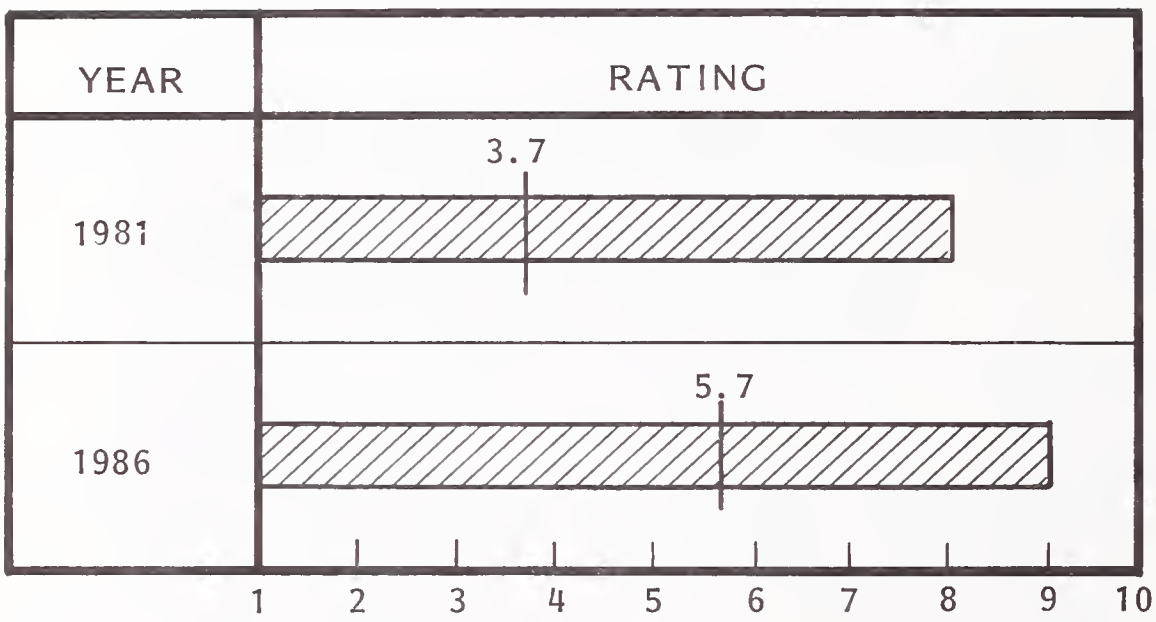


Rating: 1 = Not Essential, 10 = Very Essential

NOTE: 10% of the highest and 10% of the lowest responses were eliminated from this exhibit.

EXHIBIT III-26

RESPONDENTS' RATINGS,
ESSENTIALITY OF MRP



Rating: 1 = Not Essential, 10 = Very Essential

NOTE: 10% of the highest and 10% of the lowest responses were eliminated from this exhibit.

F. ENGINEERING MANAGEMENT

- CAD systems have high potential to enable better use of engineering resources.

  - The review and release process can be integrated into CAD and associated with the drawings in the CAD data base.

  - Using CAD, the activities of designers, draftsmen, and other engineering personnel may be authorized and controlled.

  - The use of standard parts and modular components may be monitored and controlled within a CAD system.

  - The status of large programs may be monitored on a up-to-date basis by extracting data from a CAD system.

- Engineering management functions are in very limited use today because of lack of availability of software on CAD systems. Large projects and engineering programs need to be completely on the CAD system before the benefits of using CAD can be achieved by management.

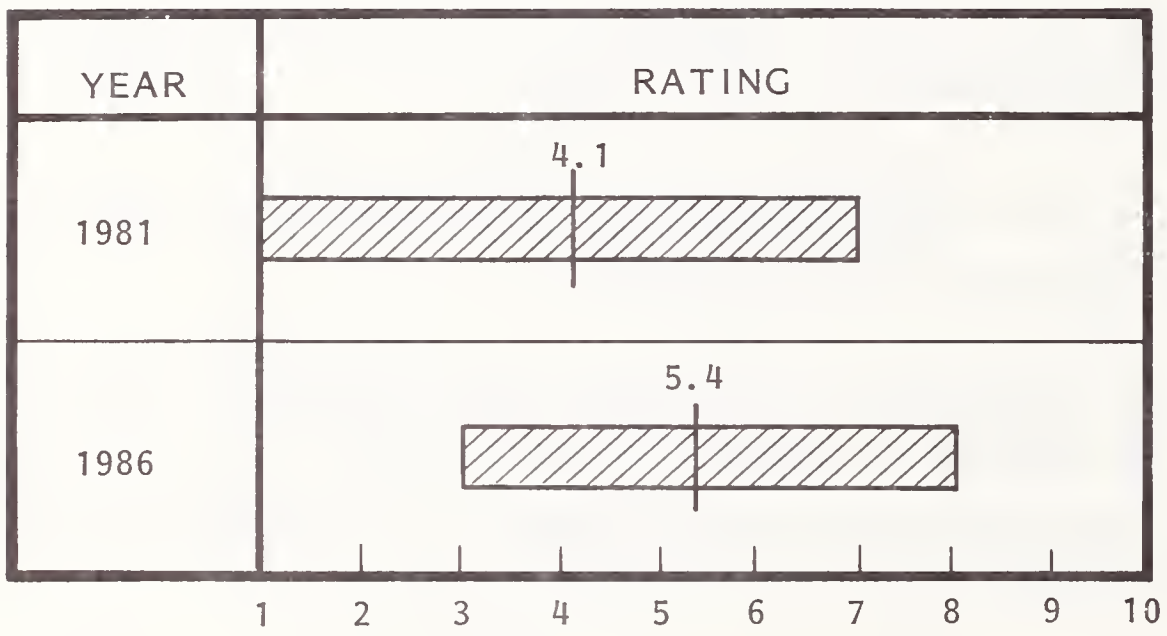
- The present and future importance of two functions related to engineering management were surveyed: statistical data and report generation, and scheduling and costing of engineering.

- Exhibit III-27 presents the ratings of current and future essentiality of CAD/CAM functions to collect and generate reports on statistics on system use.

  - The collection and reporting of this type of data is not a strong requirement now, at an average rating of 4.1.

EXHIBIT III-27

RESPONDENTS' RATINGS,
ESSENTIALITY OF STATISTICAL DATA COLLECTION
AND REPORT GENERATION



Rating: 1 = Not Essential, 10 = Very Essential

NOTE: 10% of the highest and 10% of the lowest responses were eliminated from this exhibit.

- The future rating of statistics increases to 5.4, but this is also not a strong rating compared to other functions.

- The integration of CAD/CAM systems with other systems to schedule and cost engineering resources offers additional benefits from CAD. Estimates for new engineering work may be more accurate, and schedules may realistically account for the productivity increases with CAD.

- As shown in Exhibit III-28, the interface with scheduling and cost estimating systems is not rated very essential today.

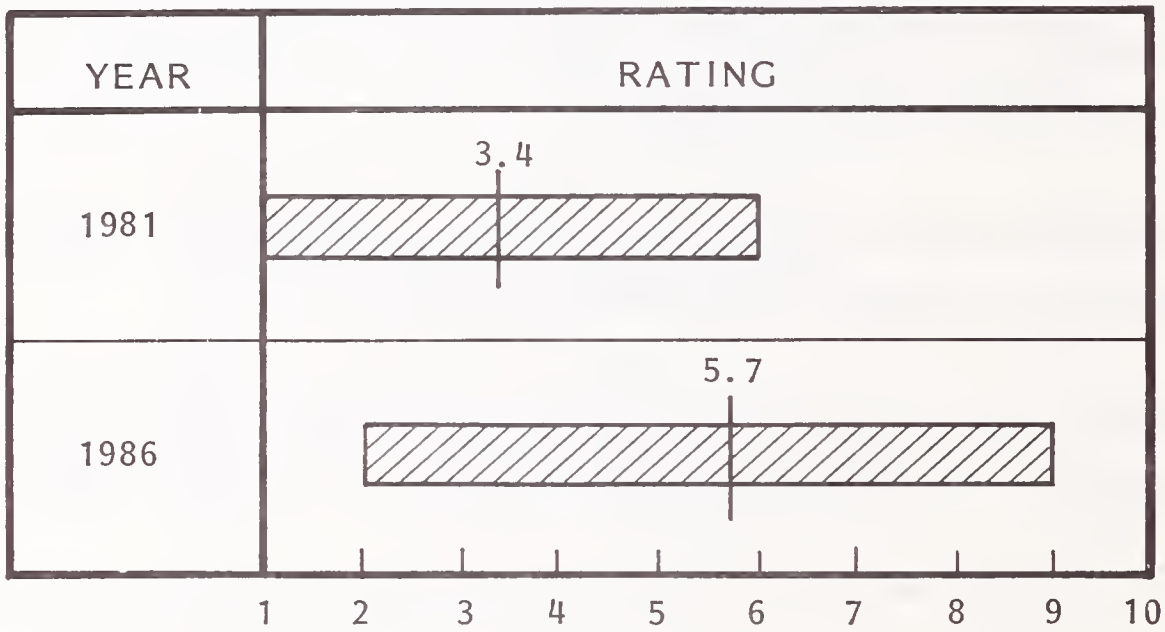
  - This low rating may reflect a general low utilization of computer-based products for scheduling, at least with the same people who are managing the CAD installations.

- The mechanical users rate the importance of an interface to scheduling and costing as much more essential to their operations in 1986.

- Some users indicated that these management functions were not rated high because they have not yet integrated CAD with other engineering activities.

EXHIBIT III-28

RESPONDENTS' RATINGS,
ESSENTIALITY OF SCHEDULING AND COSTING INTERFACE



Rating: 1 = Not Essential, 10 = Very Essential

NOTE: 10% of the highest and 10% of the lowest responses were eliminated from this exhibit.

IV TECHNOLOGICAL DEVELOPMENT

IV TECHNOLOGICAL DEVELOPMENT

- CAD systems are simultaneously evolving with both hardware and software capabilities. Some examples are:

  - Availability of integral 32-bit computers in turnkey CAD systems.

  - Future development of intelligent, remote workstations.

  - Increased software for analysis.

  - Incorporation of volumetric modelers into CAD systems (which in turn will result in increased software for other applications).

  - Development of data base management capabilities for control and management of engineering data.

A. SOFTWARE TRENDS

- Software for CAD is evolving rapidly, both for general systems and application specific software.

1. GENERAL RATING OF CAD/CAM SOFTWARE

- The general rating of the adequacy of CAD/CAM software today is high - 6.7 on a scale from 1 to 10 - as shown in Exhibit IV-1. Mechanical users expect further improvements which they rate at 7.9.

2. SPECIFIC SOFTWARE REQUIREMENTS

- The mechanical users were asked to list important software needs that were not being met by either CAD vendors or by in-house development. Exhibit IV-2 is a summary of these requirements.

- The need for a fully integrated CAD/CAM system was stated by a number of users. Present CAD systems do not provide a single system that can support all engineering tasks well.

- The need to communicate between CAD systems from different vendors and between CAD systems and host computers was again stated by several users.

  - IGES, GKS, or another standard will be necessary to provide this.

- For mechanical design definition, there is a strong requirement for better capabilities to define and work with arbitrary surfaces. Some of the specific capabilities needed are: trimming, blending, generation of fillets, intersections, and maintenance of clearance.

- The requirement for volumetric or solids modeling was expressed by a large number of users.

- One respondent stated a requirement for a 2-D to 3-D translator to build a design data base from existing drawing information.

- Many respondents expressed the need for improved finite element analysis capabilities. The needed improvements include: improved techniques for

generating models, better communication to analysis programs (on hosts), improved post-processors, and integration of thermal analysis with stress analysis.

- Extraction of mechanical properties from volumetric models such as mass, principal axes, and moments, is another analysis requirement.

- Improvements for drafting and documentation mostly dealt with improving the response of the CAD system. Specifics mentioned were faster edits and redisplays, and less degradation when additional workstations are added, or when the data base is expanded.

- The need for improved NC was expressed by several users. In addition to providing a better NC capability, turning and lathe programs are needed. One user expressed the need for post-processors which support its unique NC machines.

  - One user expressed the opinion that the "NC (provided with CAD) is primitive."

- Not all users had requirements for software additions to their CAD systems. A total of 14 users indicated that their needs were being met by their CAD systems.

3. COMMUNICATION WITH CAD SYSTEMS

- IGES was originally proposed by a group made up of representatives of the U.S. Bureau of Standards, GE, Boeing, and others from U.S. industry.

  - IGES has now been accepted as an ANSI standard.

  - Most major CAD vendors have committed to output and receive files of CAD geometry data formatted in accordance with IGES.

- GKS is a similar standard, proposed to ISO by the European CAD users. GKS is a 2-D standard and is much like SIGGRAPH-CORE in some aspects.

- SIGGRAPH-CORE is a proposed standard from graphics data developed by the ACM over the past five years. The SIGGRAPH-CORE standard is very flexible and oriented toward computer manipulation of displayed data.

- Commmunication between CAD and graphics systems is a subject of research. At the University of Rochester the multiple layers of software required to implement CORE standards have been found to result in significant loss of performance.

- There is a strong need for a communication standard such as IGES, GKS, or another.

  - Many large companies have installed CAD systems from multiple vendors.

  - Many users need to transfer data from CAD systems to existing NC or engineering analysis systems.

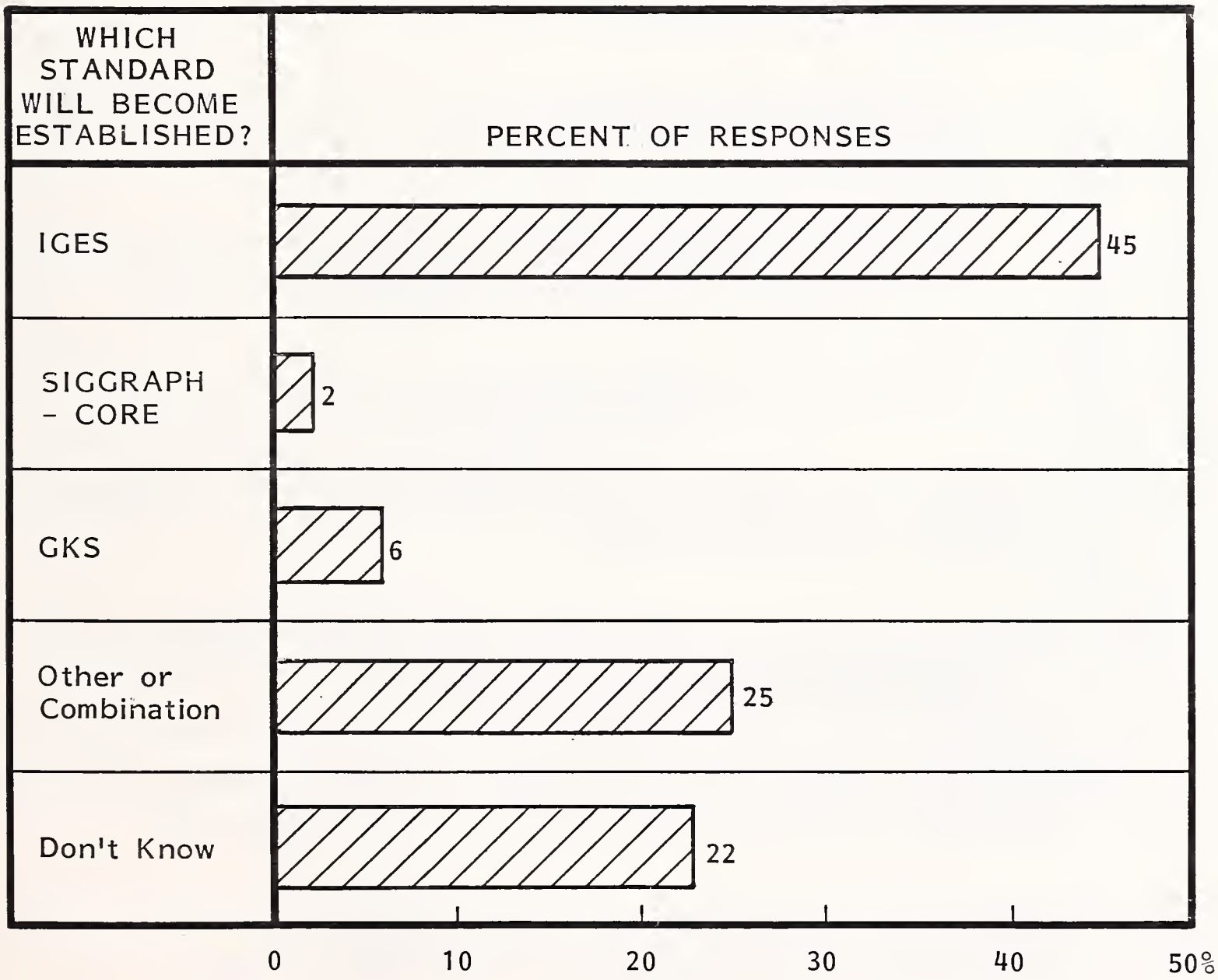
  - Some companies, who now have a single CAD vendor, want to be able to procure new systems from other vendors and avoid sole-source situations.

- The preference for communication standards by the mechanical users is shown in Exhibit IV-3. IGES will become the standard according to 45% of the responses.

  - There may be some debate on whether IGES is already the standard. CAD vendors are demonstrating IGES transfers of data, but the availability of this to their customers is not clear.

EXHIBIT IV-3

RESPONDENTS' VIEWS OF STANDARDS FOR CAD/CAM



- IGES will require continued support by vendors. If a change is made to their internal data structure, their programs to input/output IGES must also be changed.

- GKS has strong support in the European CAD community. There may be a separate standard, or there may be a future reconciliation between IGES and GKS.

- The very strong need for a communication standard was additionally emphasized by 15 of the respondents.

  - One user stated: "I don't care which (standard is adopted), I just want a standard."

  - One large company has built its own system for communication between turnkey CAD (CADAM) and its in-house developed system.

  - One user complained that IGES is being developed too slowly.

- A Japanese user stated that there is no graphic standard in Japan and that it will take 10 years to establish one.

4. SOURCE OF SOFTWARE ADDITIONS AND ENHANCEMENTS

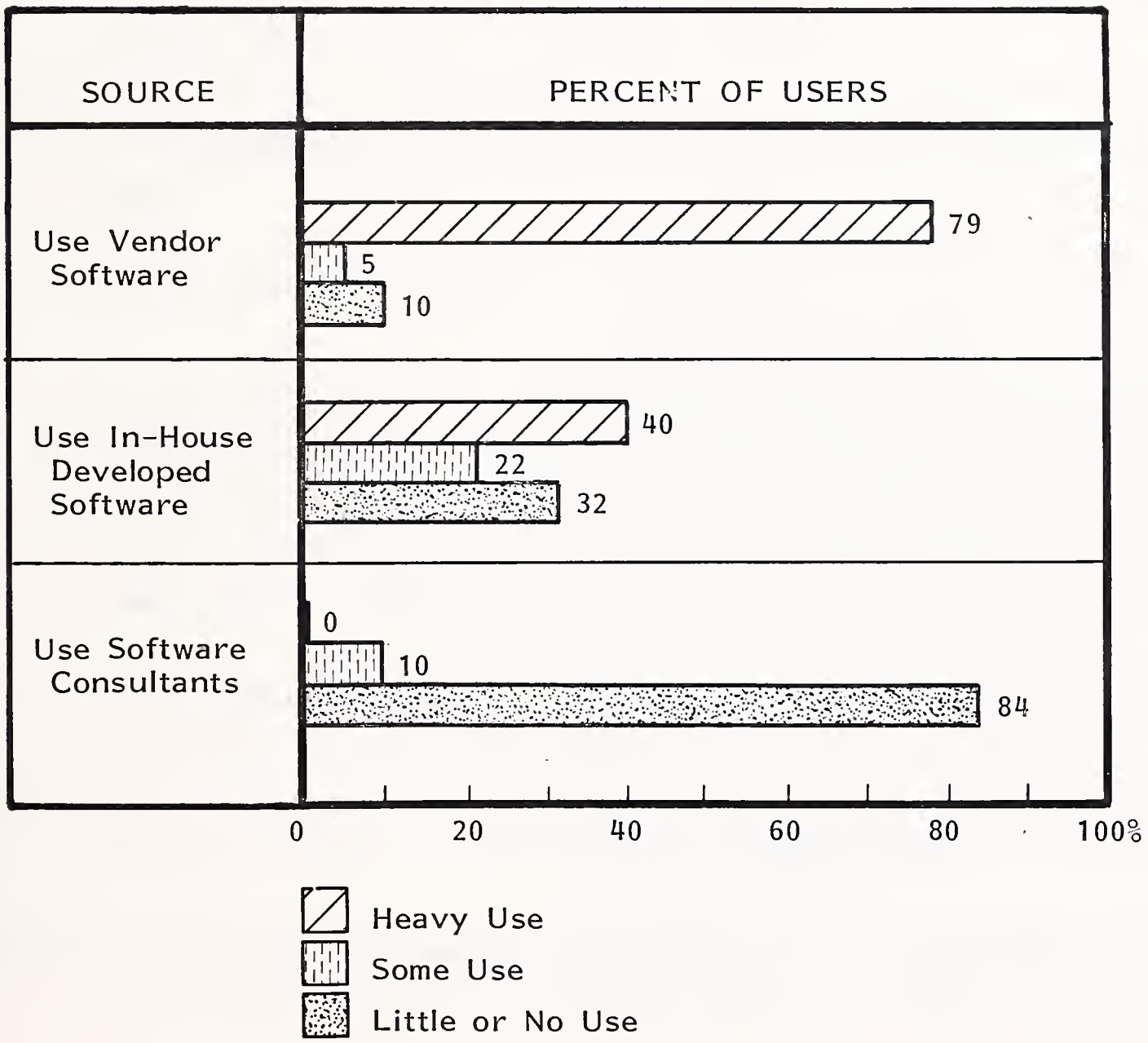
- Mechanical CAD users are primarily dependent on CAD vendors to upgrade and add to their system's capabilities. Exhibit IV-4 shows their relative dependence on in-house, vendor, and consultant software sources.

- In-house developed software is important to many users but receives heavy use in about half as many companies as vendor developed software.

- Custom software developed by outside consultants is not an important source today.

EXHIBIT IV-4

RESPONDENTS' SOFTWARE SOURCES:
ADDITIONS AND ENHANCEMENTS



- There is no major difference in these dependencies between the discrete, mobile/transportation, and aerospace product categories.

  - This is somewhat surprising because a number of aerospace companies are known to have large in-house staffs working on CAD.

5. CAD USER GROUPS

- Membership and participation in CAD user groups is high. Of the 66 users who responded to this question, 52 are members.

- In addition to the user groups associated with the turnkey and mainframe-based CAD systems, a number of other groups were reported:

  - SIGGRAPH and NCGA.

  - DEC users' group.

  - In-house CAD users' groups in Rockwell, Ford, and GM (for CV systems).

- The users' objectives for participating in a CAD user group are:

  - To influence development priorities of the CAD vendors.

  - To gain access to software, particularly application programs developed by other users.

- The effectiveness of CAD users' groups was rated high - 6.8 average on a scale of 1 to 10.

  - However, there were a number of mechanical users who were critical of the effectiveness of CAD user groups.

6. IPAD and ICAM

- IPAD and ICAM are major NASA and U.S. Air Force programs in CAD/CAM. These programs have provisions for industry participation, as observers and on higher levels.

- About 80% of the mechanical CAD users do not participate in either program. Exhibit IV-5 shows this result.

- Of the 13 participants in IPAD, 6 were aerospace companies. Of the 14 participants in ICAM, 8 were aerospace companies.

- Neither IPAD nor ICAM are currently having a large effect on CAD/CAM usage.

7. CAD/CAM INTEGRATION

- The integration of CAD and CAM systems means that engineering, design and drafting, and manufacturing personnel can all work in the same data base and use common interactive graphic, analysis, and modeling procedures. The effective integration of these systems promises much in further benefits from CAD and CAM technology.

- The survey results for mechanical users concerning the state of CAD/CAM integration, now and in 1986, are summarized in Exhibit IV-6.

- Users do not consider CAD/CAM to be integrated at present.

- A significantly higher degree of integration is expected in 1986 but, according to the users, there will still be much room for improvement.

EXHIBIT IV-5

IPAD AND ICAM PARTICIPATION

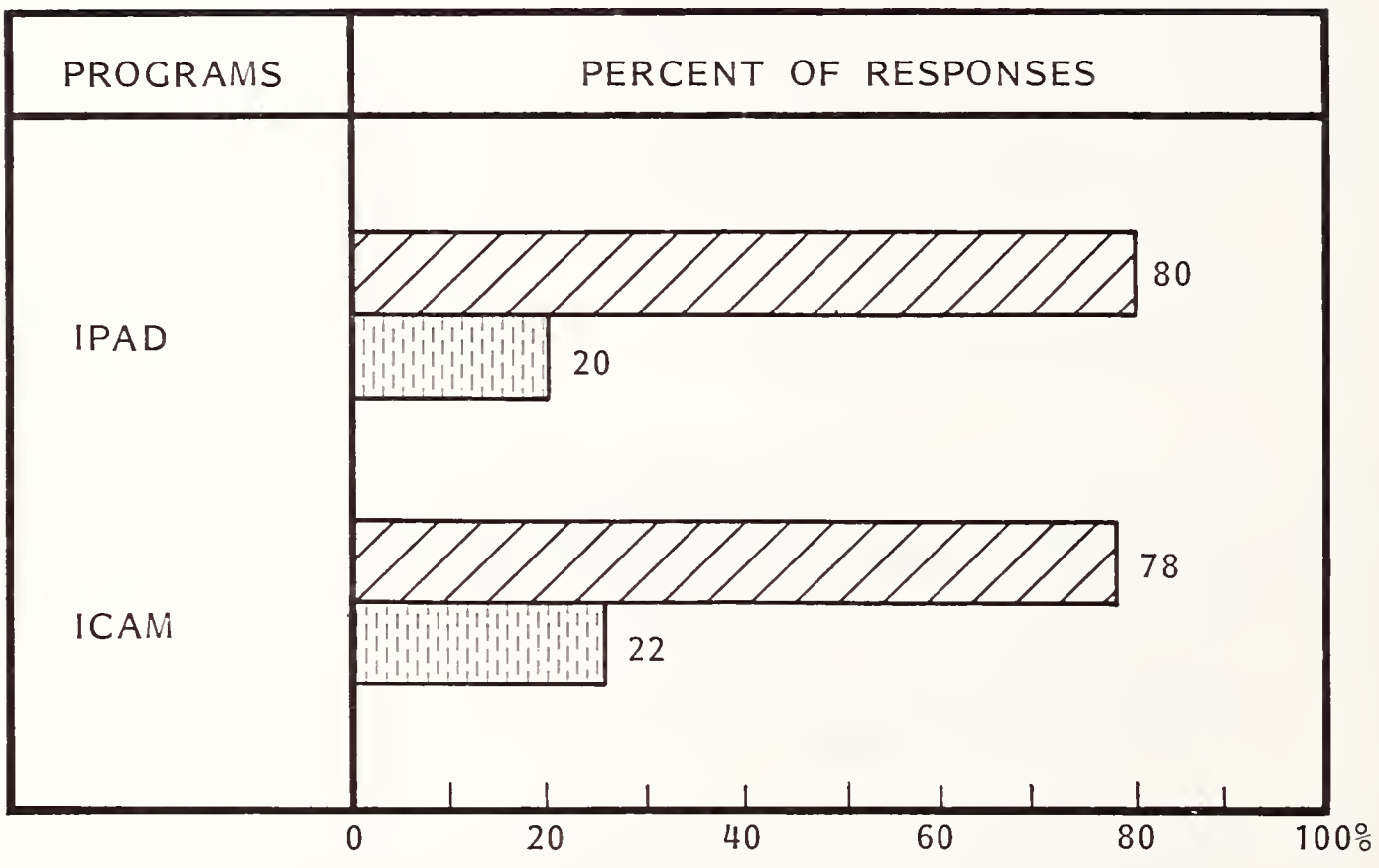
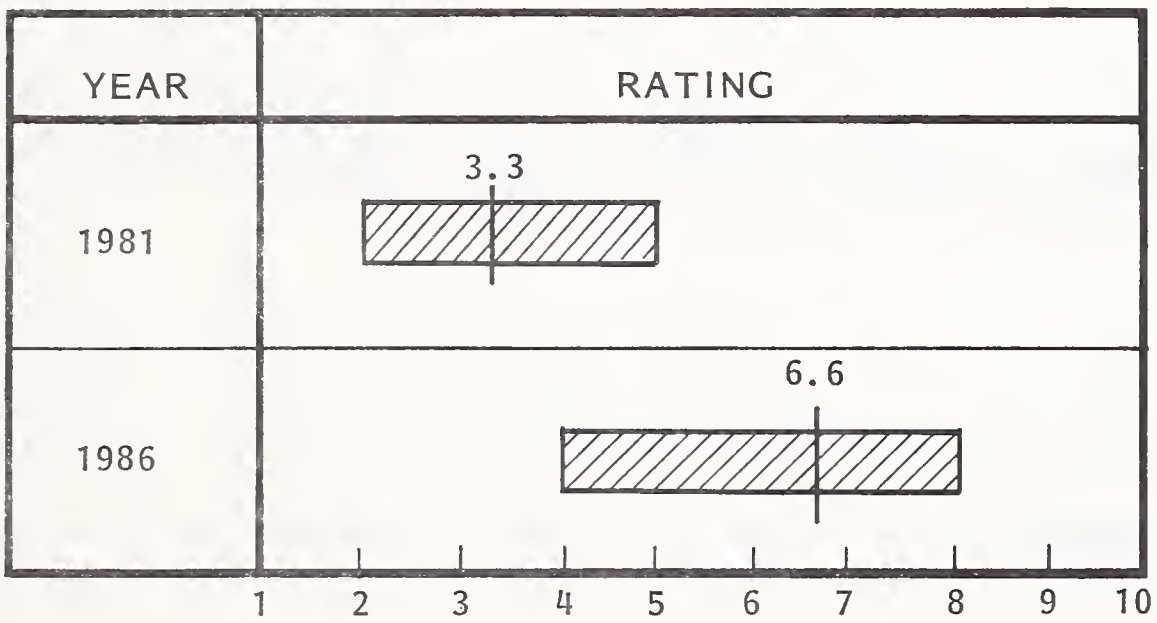


EXHIBIT IV-6

RESPONDENTS' RATINGS,
STATUS OF CAD/CAM INTEGRATION



Rating: 1 = No Progress at all, 10 = Fully Integrated

NOTE: 10% of the highest and 10% of the lowest responses were eliminated from this exhibit.

8. DATA BASE FOR INTEGRATED CAD/CAM

- The organization of the data base is a key issue for CAD/CAM integration. The data base must provide for storage of design shape definitions, engineering analysis models, drawings, process plans, NC programs, and other data. The same geometric model created in the design definition phase needs to be used to generate finite element meshes, engineering drawings, NC programs, and for other applications. Associations between data need to be maintained.

- Users were asked what they considered to be obstacles to achieving a data base for integrated CAD/CAM. The obstacles considered to be most and least important are shown in Exhibit IV-7.

  - These data have been analyzed using the same highest (or lowest) and "high" (or "low") technique used to analyze CAD selection factors (Exhibit III-7) and CAD benefits (Exhibit III-8).

- The three most important obstacles to an integrated CAD/CAM data base are:

  - Organizational factors - an integrated CAD/CAM system will cross existing boundaries such as the division between engineering, manufacturing, and management information systems. Poor communications between these functions can be an obstacle.

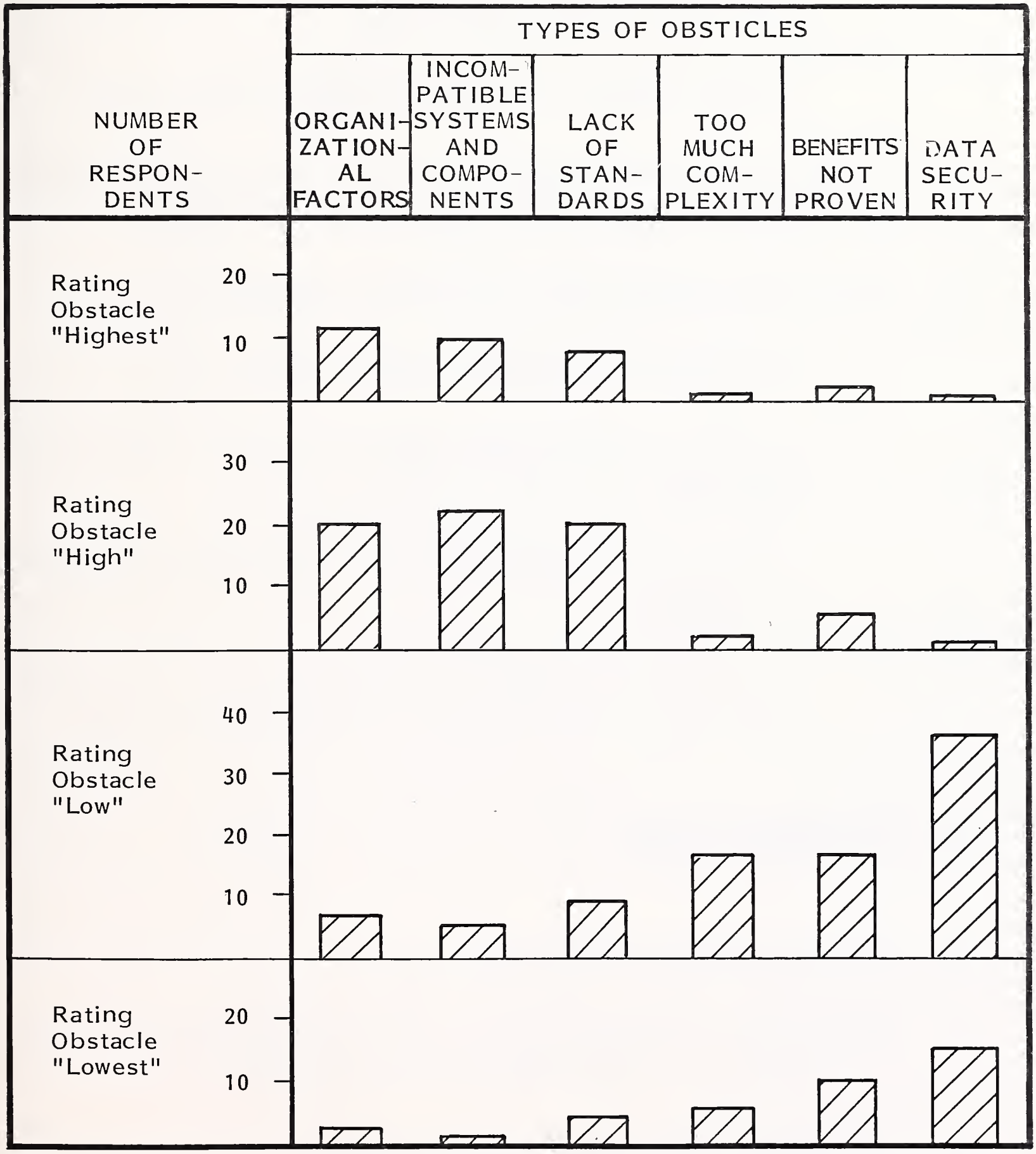
  - Incompatible systems and components - CAD, NC, and data processing systems which are in place today do not have the capability of transferring CAD/CAM information between them.

  - Lack of standards - the same information is treated differently in different organizations.

- The three least important obstacles are:

EXHIBIT IV-7

RESPONDENTS' RATINGS, OBSTACLES TO
INTEGRATED CAD/CAM DATA BASE



- Concern with data security - transferring data within a company should not affect security.

- Unproven benefits (of an integrated CAD/CAM system) - the users consider that the advantages are evident.

- Too much complexity - this is not considered a serious problem.

- A seventh obstacle was considered: too costly. This was rated in the middle, neither a most important obstacle, nor a factor to be ignored.

- Some of the comments made concerning these obstacles were:

  - Inertia, doing it the old way, is a major problem.

  - The need for an integrated data base must be accepted by upper management.

  - To make use of an integrated data base will be like "moving from an art to a science."

  - The existence of an integrated CAD/CAM data base will make the role of engineering and manufacturing management more important.

B. HARDWARE TRENDS

1. DISPLAY TERMINAL TECHNOLOGY

- The mechanical CAD/CAM users were surveyed on the importance of major types of display terminal technology to their applications.

- Four types of display technology were surveyed:

- Storage tube - similar to the Tektronix 4014 terminal.

- Calligraphic - also called a vector refresh or stroke driven display.

- Raster scan - television technology and presently limited to approximately 1000 x 1000 picture elements.

- Color - available at low cost with raster scan display and at high cost with calligraphic displays.

- The storage tube is the predominant display type in use in today's turnkey CAD systems. CAD systems offered with computer mainframes, such as the IBM CADAM system and MCAUTO's CADD system, use calligraphic technology. Over the last year, turnkey CAD systems are being delivered with raster scan display terminals. These are currently offered with single color resolutions to 1,000 lines and multicolor to 500 lines.

  - Storage tube displays are considered adequate to meet the needs of mechanical applications today. Exhibit IV-8 shows an average rating of 5.7, with 80% of the responses ranging from 2 to 8.

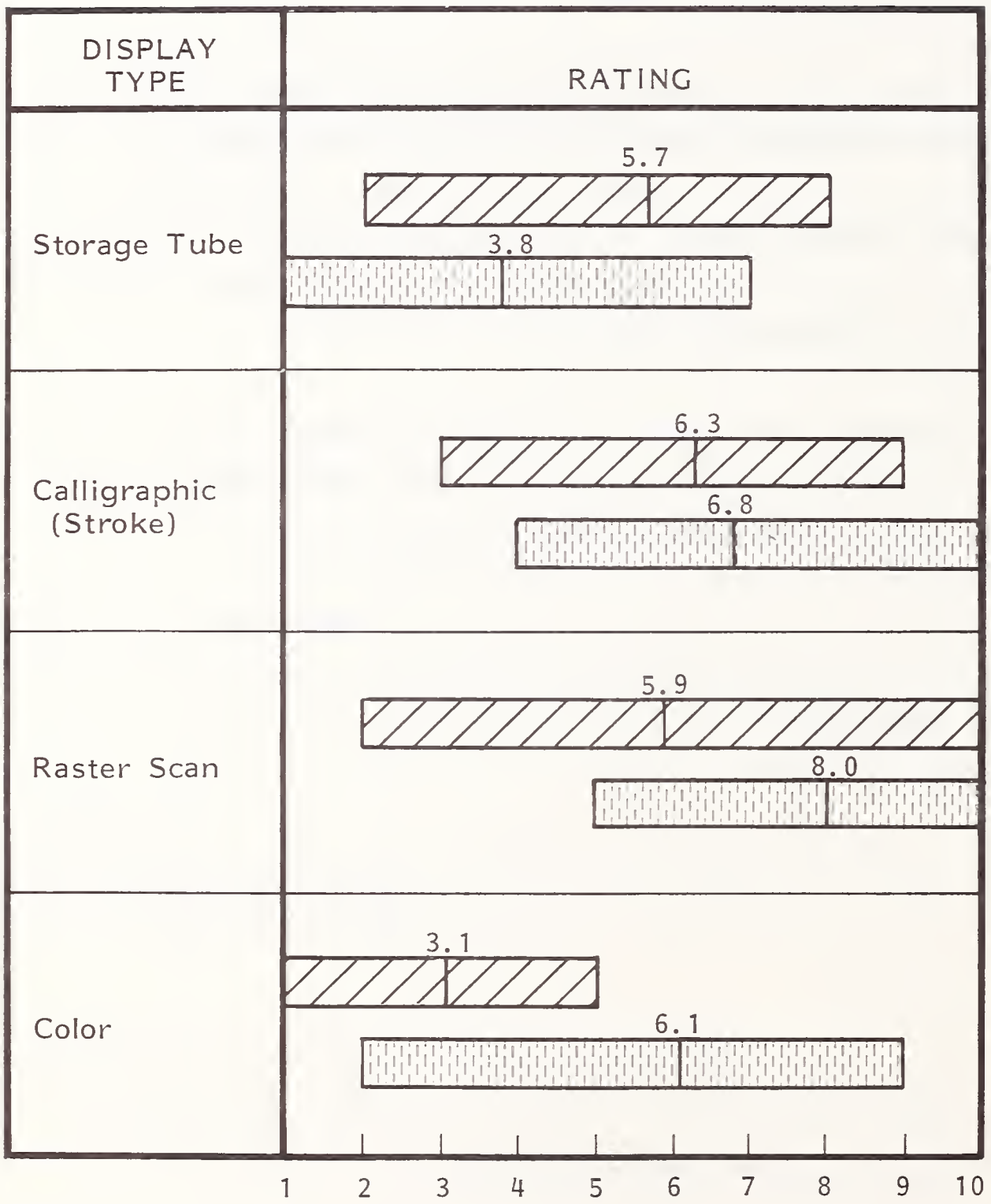
  - Storage tube displays will not be considered adequate by 1986. The average drops to 3.8 with many ratings at 1, which is defined as "totally inadequate."

  - Calligraphic displays are judged to better meet mechanical application needs, both today and for tomorrow. In 1981, these displays have a moderate advantage over storage tubes; in 1986, they will be far more desirable.

  - Raster scan displays are judged to be about equal to calligraphic for present applications. They are rated higher than calligraphic in 1986, and much higher than storage tubes.

EXHIBIT IV-8

RESPONDENTS' RATINGS, DISPLAY TERMINAL TECHNOLOGY



Rating: 1 = Totally Inadequate, 10 = Far Exceeds Needs

NOTE: 10% of the highest and 10% of the lowest responses were eliminated from this exhibit.

- Color is rated low for 1981 applications, and relatively high for 1986 applications.

- Users rated the value of raster displays to be higher than calligraphic in 1986. This rating probably is a result of the assumption that the resolution of raster displays will approach that of calligraphic in this period and that rasters will have advantages in cost, complexity of display, and remotability.

- The use of color displays in future CAD systems has been highly touted over the past two years. Additionally, color terminals are now in use in some turnkey CAD installations. Considering this, the rating of color as the least important technical factor today, lower than the ratings for calligraphic and raster in 1986, is also surprising.

  - In their comments on display technology, 33 of the users said that they expect to be using color displays within the next five years. These displays are expected to be improved, offering more colors and better contrast than those now in use.

- The mechanical CAD users were asked to identify major changes in display terminals expected over the next five years. In addition to the response on color, other items that received a large number of responses are shown in Exhibit IV-9.

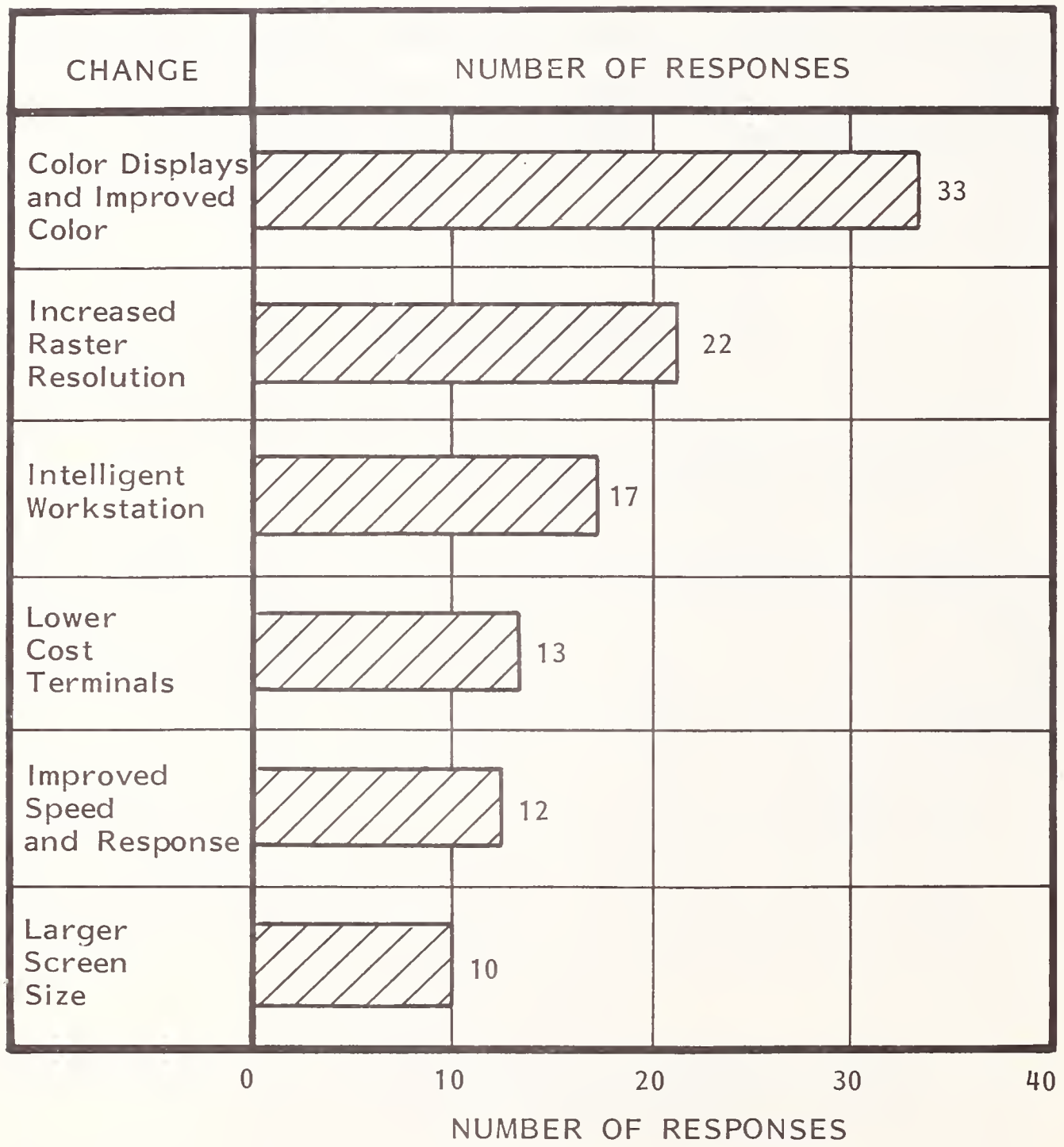
  - The resolution of raster displays is expected to increase and these displays will be used. The present resolution is viewed as a serious limitation and an increase to 2000 x 2000 lines is expected. This improved resolution is expected to be adequate.

  - The need for larger screen size expressed by 10 users reflects the same dissatisfaction with the present resolution of rasters.

  - Intelligent workstations were singled out by 17 users. These plans result from two factors: the need to remotely locate workstations and

EXHIBIT IV-9

SUMMARY OF RESPONDENTS' EXPECTATIONS OF CHANGES IN DISPLAY TECHNOLOGY IN THE NEXT FIVE YEARS



to unload a host or CAD processor so the system becomes more responsive.

- The users expect to acquire new terminal technology to improve cost and performance. Improved speed and responsiveness was listed by 12, and lower cost terminals by 13. Present systems are considered deficient, particularly in responsiveness.

- Many other display and terminal improvements are expected and needed by some of the users surveyed:

  - Better plotters with increased throughput, color capability, and direct microfilm output (COM).

  - Voice command.

  - Improved quality and contrast.

  - Solids display presenting shaded images of complex objects for real-time viewing.

2. DISTRIBUTED DATA BASES

- One aspect of achieving an integrated CAD/CAM system is to distribute the CAD data base where it can be economically accessed by all users in engineering and manufacturing.

  - A distributed data base involves both hardware and software technology.

    . Software is required to provide a single, nonredundant and complete representation of each element of data. Each user should be able to access, modify, and store data dealing with representations of the data which apply to his discipline.

. Hardware is required to minimize the costs of communication, which will include large amounts of geometric data. The hardware must also make efficient use of physical storage and provide fast access and retrieval.

- The users were asked if the technology for distributed CAD/CAM data bases was available today, and if it will be available in 1986. Exhibit IV-10 shows these results.

  - Most users do not believe that the technology will yet support distributed data bases.

  - Most believe distributed data bases will be practical in 1986.

3. MAINTENANCE

- As the dependency of an engineering department on CAD increases, its availability directly affects the productivity of the department. The quality of maintenance is considered to be a very important aspect of CAD by the users.

- Of the 76 users surveyed, 68 (89%) receive maintenance of their CAD systems with a maintenance contract.

  - Other maintenance included:

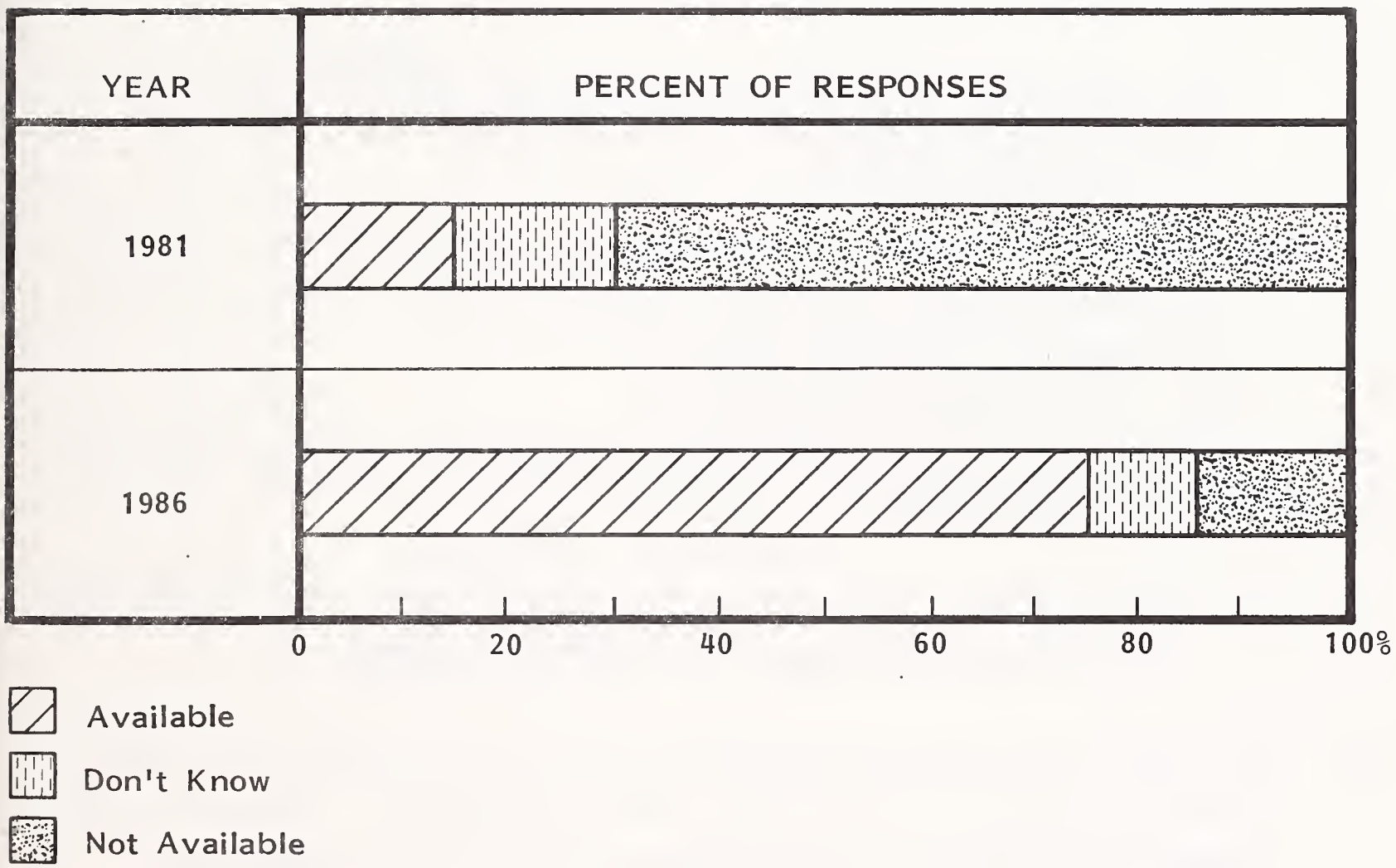
    . Time and materials - six users (8%).

    . In-house maintenance - nine users (12%).

  - Some companies reported using combinations of these.

EXHIBIT IV-10

RESPONDENTS' ASSESSMENT OF AVAILABILITY OF DISTRIBUTED DATA BASE TECHNOLOGY



- Software maintenance was also contracted on a monthly basis by 34 (44%) of the companies. Software maintenance was also reported to be bundled with hardware by 27 companies (35%).

  - Time and materials maintenance is used by 11 companies (14%).

- The quality of the hardware maintenance is rated higher than that of software maintenance, as shown in Exhibit IV-11.

- There is a large spread of responses for both software and hardware.

  - Some users are "highly pleased."

  - Some users complained of slow response, no off-hours response, and a degradation in response since they first obtained their CAD system.

  - For CADAM, IBM provides hardware maintenance, and Lockheed provides software maintenance. This has resulted in problems for some users.

- The most often reported maintenance problem is the shortage of qualified CAD maintenance people.

  - This problem is aggravated by the rapid growth of CAD installations and competitive demands for people with these skills.

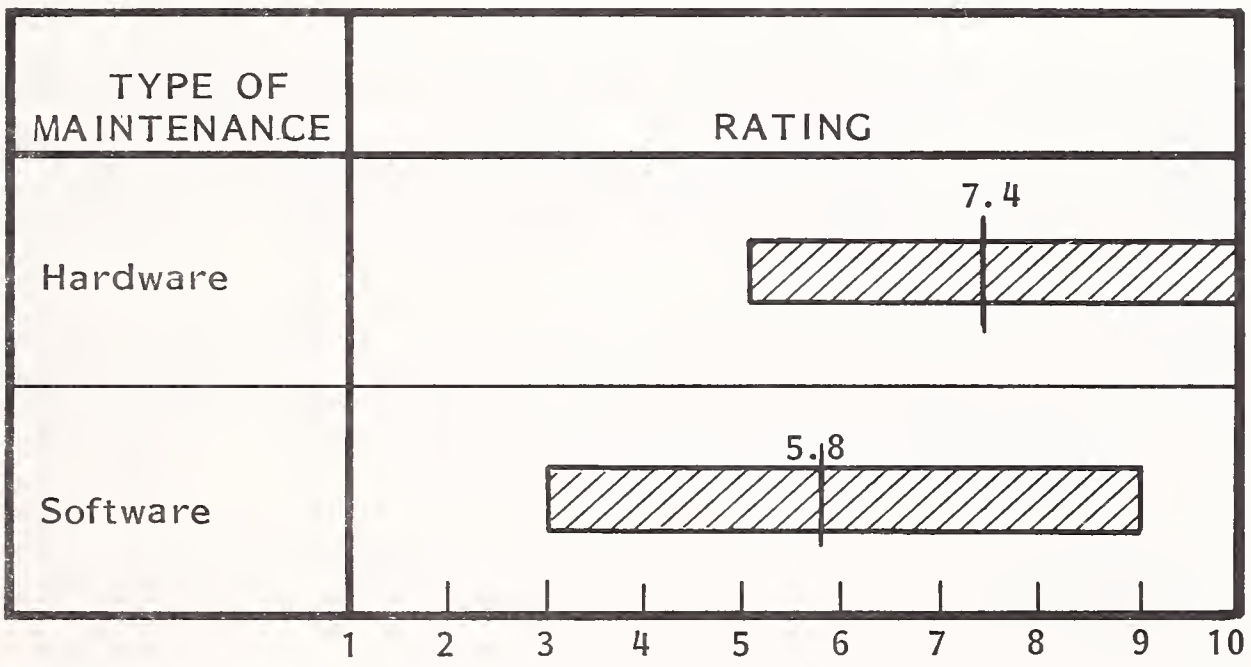
- The users were asked how important maintenance performance on present systems would be to their future CAD procurements. Almost all the companies consider this demonstrated performance to be very important.

  - One company stated: "If not for the maintenance, (we) would be using a different vendor."

  - Other remarks were:

EXHIBIT IV-11

RESPONDENTS' RATINGS,
QUALITY OF MAINTENANCE



Rating: 1 = Inadequate, 10 = Superior

NOTE: 10% of the highest and 10% of the lowest responses were eliminated from this exhibit.

- "Vital."
- "A heavy consideration."
- "Companies selling quality machinery are going to maintain it."
- "One of five major categories to be considered for next purchase."
- "Since productivity is 4:1, a down system is like losing four people."

4. BUSINESS GRAPHICS

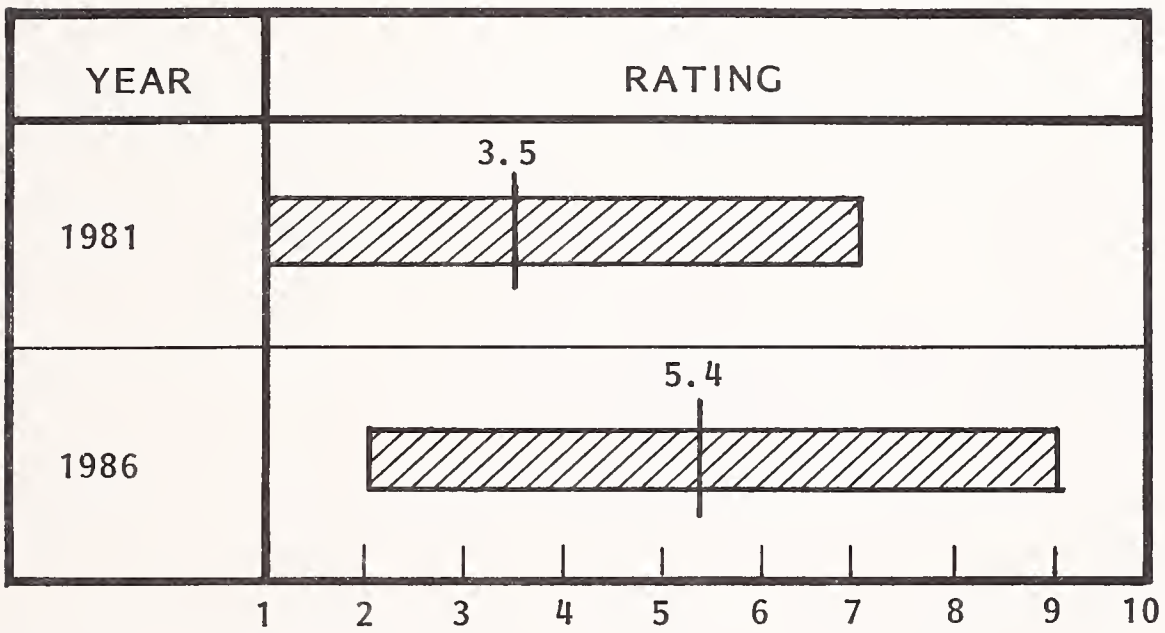
- Concerning the use of business graphics, independent of CAD, 47% of the users reported that their company is now using computer-based business graphics. In 1986, these users expect that 86% of their companies will be using it.

- Business graphics is not considered to be tied to CAD today, and there is a wide divergence of opinion on whether it will be related in 1986. Exhibit IV-12 shows these ratings.

  - Individual opinions of users were: "Prefer to see it totally divorced," and "not even related."

EXHIBIT IV-12

RESPONDENTS' RATINGS ON THE IMPORTANCE OF CAD TO BUSINESS GRAPHICS



Rating: 1 = Not Important, 10 = Very Important

NOTE: 10% of the highest and 10% of the lowest responses were eliminated from this exhibit.

V CAD/CAM VENDOR OFFERINGS

V CAD/CAM VENDOR OFFERINGS

- Present CAD/CAM products are specialized systems for engineering and design (CAD), structural analysis, and manufacturing (CAM).

- CAD systems are sold as turnkey systems; low-cost standalone CAD systems for drafting, and large mainframe-based systems which can support many graphics terminals.

- Computer-based systems for structural analysis are licensed for installation on mainframes, rented by remote computing services, provided by consultants and, to a limited degree, integrated with CAD systems.

- CAM products are sold as services on remote computing services, on stand-alone in-house systems, as licensed software on mainframes, and as an integrated capability in CAD systems.

A. CAD SYSTEMS

1. HARDWARE

- Turnkey CAD systems for mechanical applications are offered with similar configurations of minicomputers, workstations, and peripherals. Exhibit V-1 summarizes major elements of the hardware configuration of these systems.

EXHIBIT V-1

TURNKEY CAD HARDWARE SUMMARY

VENDOR/ SYSTEM	COMPUTER(S)	DISPLAY CHARACTERISTICS			WORKSTATION		CONFIG-URATION
		TYPE	COLOR	RESOLU-TION	INTER-ACTION	REMOTE	
Applicon	DEC (PDP-11 and VAX)	Storage	B/W	4,000	Tablet-Menu A*	No	Single
		Raster	B/W	1,000			
		Raster	Color	500			
Autotrol AD380 and GS 2000	UNIVAC (V77) DEC (VAX)	Storage	B/W	4,000	Menu-Function Keybd.	No	Separate Alpha Screen
Calma	Data General	Storage	B/W	4,000	Tablet-Menu	No	Dual Screen
		Raster	B/W	1,000			
		Raster	Color	500			
Computervision Designer	Computervision CGP100/200	Storage	B/W	4,000	Tablet-Menu	No	Single
		Raster	B/W	1,000			
		Raster	Color	500			
Gerber IDS-80	Hewlett Packard	Storage	B/W	4,000	Switch Overlay	No	LED Read Out
Intergraph	DEC (PDP-11 and VAX)	Storage	B/W	4,000	Tablet	No	Dual Screen
		Raster	B/W	1,000			
		Raster	Color	500			
McAUTO Unigraphics	DEC (PDP-11 and VAX)	Storage	B/W	4,000	Switch Overlay	No	Separate Alpha Screen

*A = SYMBOL RECOGNITION

- With the exception of Computervision, all turnkey CAD vendors use a minicomputer provided by a computer manufacturer. These computers are usually not modified and use the operating system provided with the computer.

- Storage displays are offered by all turnkey CAD vendors but are rapidly being phased out by most in favor of raster displays.

- Raster displays are integrated into turnkey CAD workstations and provide improved dynamics and color as an option.

- Resolution of raster is presently limited to about 1,000 lines with monochrome (B/W) displays and 500 lines with color.

- Interactive methods generally use menus on tablet-stylus pads combined with keyboards and other input devices. Variations with plastic overlays on arrays of switches, or touch sensitive panels are offered by some.

- Many of the turnkey CAD systems presently offer a workstation with sufficient local intelligence to operate efficiently and at low cost at a remote location over a telephone line.

- Computer systems used for turnkey CAD are tending toward 32-bit configurations. These systems, such as the VAX, provide processing power and price/performance that approach many mainframes.

- Resolution of raster displays is expected to improve, perhaps double in the next two years. The speed of these displays in pan, zoom, and in changing viewpoints for a 3-D model will increase severalfold.

- Workstations will have more intelligence at equal or lower cost. This intelligence is expected to allow local CAD functions to the degree that remote operation is feasible.

2. SOFTWARE

- Turnkey CAD systems have been extensively used for drafting over the past 10 years. These software functions are well developed with each turnkey CAD system.

- All turnkey CAD vendors listed in Exhibit V-1 offer 3-D wireframe and surface definition capabilities.

- Applicon and Intergraph offer volumetric modeling today. The Applicon system is licensed from Mathematical Applications Group, Inc. (MAGI). Other volumetric modeling systems are expected to be obtained by CAD vendors by license and integrated with their systems. Two volumetric systems being offered on this basis are ROMULUS (Shape Data Ltd.), and EUCLID (Matra, a large French corporation).

- Most turnkey CAD systems offer analysis capabilities with some finite element modeling capabilities. The resulting models are transferred to mainframes for analysis processing. Improved capabilities in this area which integrate available finite element modelers are expected to be offered in the next year.

- Family of parts classification systems, combined with manufacturing functions such as process planning are now offered by some turnkey CAD vendors. One of these is Computervision's offer of the MICLASS system.

- Most turnkey CAD systems offer integrated NC capabilities. These capabilities are limited in functions, degree of automation, and compatibility with existing NC languages and post-processors. Interfaces to transfer data into existing NC programs such as COMPACT II (MDSI) are now offered with most systems.

B. MAINFRAME BASED CAD

- The dominant mainframe-based system today is CADAM, marketed by IBM with software support by Lockheed.

- CDC offers a CAD system on their mainframes based on licensed software: AD2000 (acquired from MCS) and Synthavision (acquired from MAGI).

- Other mainframe computer companies have CAD projects and may offer CAD products with their mainframes in the future.

- MCAUTO has installations of its CADD system operating on IBM mainframes at several aerospace companies.

- CADAM user terminals are IBM 3350 calligraphic displays or an equivalent display provided by companies such as Adage or Vector General.

- Light pen command selection from menus on the calligraphic display is the method for command input with CADAM.

- CADAM software functions are similar to most turnkey CAD systems except that present configurations are 2-D. A 3-D version is expected soon.

C. LOW-COST STANDALONE CAD SYSTEMS

- A number of low-cost CAD systems for drafting applications are now being sold.

  - Summagraphics has been installing a small system operating on a Data General Nova for several years. This system has recently been converted to a raster display.

- A.M. Bruning is marketing a small CAD system with a raster display. This system is acquired by license.

- Low-cost standalone CAD systems typically sell for $40,000 to $70,000 today, with a minimum performance plotter. They generally provide only 2-D drafting capabilities and have lower performance than turnkey CAD systems.

- Competition for these systems is expected from turnkey CAD vendors when remote intelligent terminals are introduced.

D. ANALYSIS PRODUCTS

- Specialized software products for engineering analysis are marketed today by many companies. The most significant of these are programs for finite element mesh generation, analysis, and post-processing. Some of the companies offering these products are:

  - MacNeal-Schwendler offers NASTRAN.

  - SDRC offers Supertab.

  - PDA offers Patran.

- Finite element analysis products are currently marketed as license programs for mainframes and by remote computing services. SDRC has offered their products integrated with Applicon systems, and more integration with CAD is expected.

E. CAM SYSTEMS

- CAM functions which are closely associated with engineering are process planning and NC programming. Currently, products are offered for both functions, but the NC products represent the largest usage by far.

- NC programming systems are sold on remote computing services, as stand-alone minicomputer-based systems, and on a license basis on in-house mainframes. MDSI and UCC are examples of major vendors in this market.

APPENDIX A: CASE STUDIES

APPENDIX A: CASE STUDIES

- These case studies are representative of the histories of users of each mechanical category: Discrete, Mobile-Transportation, and Aerospace.

A. DISCRETE PRODUCT MANUFACTURER

- "ROTOR-CO" is a division of a corporation producing diverse products. The division's products are large, rotating machines for processing materials.

- ROTOR-CO has about a 100-person engineering staff. Of these, about 50 are draftsmen and detailers. About 10 of the staff are designers who create layouts of new products.

- ROTOR-CO's active product lines are made up of 10 major product lines, but each of these have many modular variations created in response to the needs of individual customers.

- An initial Computervision CAD system was acquired in early 1980 after about a one and one-half years of study and evaluation.

  - Information was gathered on leading CAD systems for mechanical design: Applicon, CADAM, AD2000 and others.

- ROTOR CO's engineering managers attended seminars, vendor sponsored meetings, demonstrations, and visited other users of CAD systems.

- An initial CAD plan was prepared with justification based on the direct ROI on drafting applications. After several months it was apparent that the corporation was not going to approve it.

- After further involvement of corporate engineering and preparation of a second plan, the CAD purchase was approved.

- Since its installation, the productivity of the Computervision CAD installation has been as expected, perhaps even a little better.

  - The plan included a long learning period - in the order of nine months - to create a CAD data base and gain proficiency.

  - The system has been expanded to eight stations.

  - The system is very unresponsive under heavy loading and this is a concern to ROTOR-CO.

- The designers are now beginning to use the system.

  - Their initial reaction is that creation of the designs on the CAD system will further increase the payoff and reduce product development time.

- ROTOR-CO's engineering department plans to further expand the system over the next two to four years so that all engineering and design uses CAD.

- Integration with manufacturing is viewed as an area with high additional payoff.

- ROTOR-CO's manufacturing is well organized and productive. It is considered to be key to the profitability of ROTOR-CO.

- ROTOR-CO makes heavy use of NC and plans to further expand their NC use over the next five years. Manufacturing produces NC programs using the COMPACT II timesharing service of MDSI.

- CAD/CAM integration with ROTOR-CO's MIS system, which uses IBM mainframes is also considered important.

- A ROTOR-CO committee is investigating the integration of CAD, CAM and MIS systems and is expected to make recommendations early next year.

- Other divisions of ROTOR-CO's parent corporation now have effective installations of CAD.

  - These include Applicon and CADAM, as well as Computervision.

  - Discussions of IGES and other means of transferring data between these systems are going on.

B. MOBILE-TRANSPORTATION MANUFACTURER

- GRIPPER is a large division of a transportation company producing construction equipment. Their products are well known for quality and functional capabilities.

- In the early 1970s, GRIPPER began to intensively apply computers to their engineering.

- The first applications were for finite element analysis of key structural parts of their machines. This work was initially done using CDC's network services.

- A turnkey CAD system was acquired for drafting in the mid 1970s. This Applicon system has since been greatly expanded.

- GRIPPER has been committed to providing an integrated system for Computer Aided Engineering over the past five years.

  - They have acquired VAX systems with many graphic terminals in engineering.

  - AD2000 has been provided on the VAX for use in creation and analysis of design geometrics.

  - CAD and analysis programs have been added by in-house staff and by consultants. This includes provisions to transfer data into their Applicon drafting system.

- GRIPPER is making progress toward a fully capable Computer Aided Engineering facility, but are also encountering problems.

  - They now have a diverse system with components from different CAD vendors.

  - The costs of supporting and extending their own CAD software are high.

  - There is still a long way to go to reach their engineering goals which include a solid modeling capability.

- GRIPPER remains committed and believes their CAD systems are essential to their product engineering and development.

C. AEROSPACE MANUFACTURER

- SWEPTWING Aircraft Corporation produces military aircraft and missile systems for the U.S. government and for export.

  - SWEPTWING is multidivisional, located primarily in southern California.

  - The engineering staff of SWEPTWING is large and sophisticated.

  - SWEPTWING Manufacturing uses extensive NC, under direct control of remote IBM computers. The NC programming language is APT, and the post-processors are programmed and supported by SWEPTWING's in-house staff.

- SWEPTWING justified and procured an initial CADAM installation in the late 1970s. This system has been greatly expanded so that there are now CADAM installations at several divisions, averaging 75 stations at each facility.

  - Designers and draftsmen are trained on CADAM by in-house specialists. There is more than one operator per station and the designers also have drafting boards for sketching and layout.

  - All final documentation is produced on the CADAM system.

  - Much of the NC programming is done with CADAM but is limited because of the unavailability of surface models.

- SWEPTWING considers CADAM as a CAD system suitable for drafting and documentation. In 1978 they initiated their own in-house program to develop a system for layout, 3-D surface definition, and other engineering tasks which CADAM does not perform.

- SWEPTWING's in-house CAD system is partially operational. It has about 20 intelligent terminals installed today. These are used for both aircraft design and further development of their system.

- SWEPTWING continues to aggressively develop their own system and to expand CADAM. They are totally involved in CAD/CAM as an essential part of their company.

APPENDIX B: GLOSSARY OF TERMS

APPENDIX B: GLOSSARY OF TERMS

AEROSPACE (product category). The subgroup of mechanical CAD/CAM users producing aerospace products such as airplanes, missiles, and aircraft engines.

ARTICULATION. Analysis of the movement of connected parts in complex assemblies.

BILL OF MATERIAL (BOM). A listing of all subassemblies, parts, and materials that go into an assembled part showing the quantities of each.

CAD (Computer-Aided Design). Application of computer and graphic technology to engineering, design, and drafting.

CAD/CAM. The integrated application of CAD and CAM.

CALLIGRAPHIC DISPLAY. A cathode ray tube display which writes each vector and character in the sequence of its commands. This display type provides high quality and good dynamics.

CAM. Application of computer and graphic technology to manufacturing engineering, planning, and control.

Computer Output Microfilm (COM). The technology for accepting digital data and recording it on microfilm at high reduction ratios and very high speeds. Useful for recording drawings as well as data.

CORE (SIGGRAPH). A proposed standard for software driving graphic devices, established by SIGGRAPH.

DATA BASE. A set of data records and files structured for a particular operating environment.

DATA BASE MANAGEMENT SYSTEM (DBMS). A software system that allows a user to structure a data base by defining the data, its organization, and the association between data elements. It also includes a data manipulation language (for access, sorting, merging, etc.) and controls for concurrent use (security, request, queueing, etc.). Functions as a common interface to multiple applications.

DATA TABLET. A device consisting of a pad and stylus used to input commands, designate elements, or to digitize drawings for a CAD system.

DISCRETE (product cateogry). The subgroup of mechanical CAD/CAM users producing discrete products such as conveyors, hand tools, electric motors, and air filters.

DISPLAY. A simple graphics terminal or the graphics display component of a more complex terminal.

DISTRIBUTED DATA BASE. A data base which is physically located at multiple sites, with each site having a part of the total data base. The sites are usually linked to a central site as well as having access to each other.

DISTRIBUTED PROCESSING. Multiple computers simultaneously processing elements of a CAD or CAM task.

DYNAMIC MOTION (display). A capability of a display to rapidly and continuously change the viewpoint under operator command.

ENGINEERING/MANUFACTURING DATA BASE. A combined CAD/CAM data base used by both engineering and manufacturing.

FAMILY OF PARTS. A process for defining generic part attributes which, when combined with user-specified parameters, will perform automatic CAD or CAM operations such as drawing, NC programming, or testing and simulation.

FINITE ELEMENT ANALYSIS. As used in this report, this includes all tasks involved in structural analysis using finite element methods: preprocessing or mesh generation, finite element analysis processing, and post-processing.

GKS (Graphic Kernel System). A proposed European standard for interchange of data between CAD systems.

GROUP TECHNOLOGY. The application of classification and coding technology to search a data base for information on similar parts and to apply this to CAD and CAM tasks.

ICAM. U.S. Air Force Integrated Computer Aided Manufacturing program for manufacturing technology.

IGES (Initial Graphics Exchange Specification). A proposed standard for the interchange of data between CAD systems. Developed by the National Bureau of Standards under contract from the ICAM program.

INTELLIGENT WORKSTATION. A CAD or CAM workstation which performs many tasks internally and independent of the host computer.

IPAD (Integrated Programs for Aerospace Vehicle Design). A NASA program to develop an integrated CAD/CAM system for aerospace applications.

KINEMATICS. Analysis of articulated assemblies.

KINETICS. Analysis of dynamic loads.

LAYERING. A technique to assign geometric and other data to spatially related layers, which can be viewed or plotted independently.

LIGHT PEN. A device used to input commands and to designate elements by pointing at or touching the display.

MANAGEMENT INFORMATION SYSTEM (MIS). A data processing system specifically designed to provide business managers with company, financial, project, or program data.

MASS PROPERTIES. Calculation of weights, centers of gravity, and moments of inertia for a closed volume.

MOBILE/TRANSPORTATION (product category). The subgroup of mechanical CAD/CAM users producing products for transportation or similar products, such as automobiles, tractors, and construction machines.

NUMERICAL CONTROL (NC). CAM technology and systems for programming and controlling numerically controlled machines.

NCGA. National Computer Graphics Association.

NC POST PROCESSORS. Computer programs to adopt generic NC commands to drive specific NC machines.

NESTING. Software to automatically or interactively arrange patterns for parts within stock material boundaries.

NETWORKING. The interconnection and control of remotely located systems and devices over communications lines.

RASTER DISPLAY. A CAD display using television technology. Currently has less resolution than Calligraphic, better dynamics than memory tubes, and lower cost.

SHOP FLOOR CONTROL. Control of the progress of each customer order or stock order through the successive operations of its production cycle and the collection of data regarding actual completion results or status.

SIGGRAPH. Special Interest Group on Graphics, an organization within ACM (Association for Computing Machinery).

SOLID MODEL. A computer based representation of a complete, enclosed object or part; the same as a volumetric model.

STORAGE TUBES. A graphics display in which the image is stored on an element behind the viewing screen. Graphics elements can be added to the stored image, but the entire screen must be erased and repainted if elements are deleted. Since this image is not refreshed as in raster or stroke tubes, there is no flicker; however, repaint time for large amounts of data can be significant compared to other technologies.

STROKE REFRESH. A calligraphic display.

SURFACE MODEL. A computer based representation of a surface patch. The surface may be of many types, including ruled, tabulated cylinders, and sculptured.

TRIMMING. The operation of removing the parts of a geometric model which extend past a designated boundary.

TRUE 3-D GEOMETRY. A geometry model for a part which can be viewed from any direction with automatic generation of correct perspective or orthographic views.

TURNKEY CAD. A complete packaged CAD system including all software, computer and other hardware, and user support and training.

VECTOR STROKE. A calligraphic display.

VOLUMETRIC MODEL. The same as a solid model.

WIRE FRAME. A 3-D representation of edges made up of line segments.

APPENDIX C: QUESTIONNAIRES

MECHANICAL USER OUTLINE

I. GENERAL

II. TECHNOLOGY ISSUES

III. PRODUCTIVITY IMPROVEMENTS

IV. SOFTWARE

V. CAD/CAM INTEGRATION

VI. MAINTENANCE

VII. CAD/CAM SUPPORT OF BUSINESS GRAPHICS

CATALOG NO. XCAD[ ][ ]

I. GENERAL

1. For the purpose of this study, INPUT defines "CAD" as the utilization of computer aids for graphics, analysis, simulation, modeling requirements, documentation and configuration control in the support of the design function. "CAM" is defined as the utilization of computer aids in the linkage of outputs from design into the manufacturing process through direct control of numerical control equipment, documentation to aid N/C programmers, bills of material, quality control and the mutual exchange of data between manufacturing and design requirements.

2. What type(s) of CAD systems do you have?

   a. Turnkey system (Applicon, CV, etc.) ____ 10

   b. Software packages for in-house computer ____ 11

   c. Custom-built system ____ 12

   d. System from a major computer supplier: (IBM, CDC, DEC, PRIME) ____ 13

   e. Remote Computing Services ____ 14

3. How many total workstations are employed?

   ____ Number
   15

4. Are the analysis and processor-intensive functions performed via workstations linked with:

a. An in-house mainframe ____ 16

b. A processor in a turnkey system ____ 17

c. A remote computing company processor ____ 18

d. Distributed processors ____ 19

e. Other (describe) ____ 20

____ 21

Comments: ____

____

5. What vendors are you currently using for CAD/CAM?

a. Turnkey Systems (stand-alone)

	Vendor	Model	System Cost
1.	____ 22	____ 23	$____ 24
2.	____ 25	____ 26	$____ 27
3.	____ 28	____ 29	$____ 30
4.	____ 31	____ 32	$____ 33
5.	____ 34	____ 35	$____ 36

b. In-house systems:

1.	____ 37	____ 38	$____ 39
2.	____ 40	____ 41	$____ 42
3.	____ 43	____ 44	$____ 45
4.	____ 46	____ 47	$____ 48
5.	____ 49	____ 50	$____ 51

5. (Cont.)

c. Remote Computing Services:

	Vendor	Product	Monthly Cost
1.	____ 52	____ 53	$____ 54
2.	____ 55	____ 56	$____ 57
3.	____ 58	____ 59	$____ 60
4.	____ 61	____ 62	$____ 63
5.	____ 64	____ 65	$____ 66

d. Independent Software Packages

	Vendor	Product	System Cost
1.	____ 67	____ 68	$____ 69
2.	____ 70	____ 71	$____ 72
3.	____ 73	____ 74	$____ 75
4.	____ 76	____ 77	$____ 78
5.	____ 79	____ 80	$____ 81

6. Please rate the following factors in terms of their impact on your system selection decision. Rate (on a scale of 1 to 10, where 10 is major impact, and 1 is no impact)

FACTOR	TURNKEY SYSTEMS	IN-HOUSE SYSTEMS	REMOTE COMPUTING SERVICES	INDEPENDENT SOFTWARE PACKAGES
a) Cost	82	83	84	85
b) Processing Capability	86	87	88	89
c) Software	90	91	92	93
d) System Flexibility	94	95	96	97
e) Access to data bases	98	99	100	101
f) Future enhancements	102	103	104	105
g) Other _____ 106	107	108	109	110
h) Other _____ 111	112	113	114	115
i) Other _____ 116	117	118	119	120

Comments: _____

_____

_____

7. In your opinion, which vendors have the best systems for your applications meeting the following requirements? (Please rank vendors, starting with the best, in the first column)

RANK / APPLICATION	VENDOR #1	VENDOR #2	VENDOR #3	VENDOR #4
a) Drafting	121	122	123	124
b) Design Analysis	125	126	127	128
c) Modeling, Simulation	129	130	131	132
d) N/C outputs	133	134	135	136
e) Direct process control	137	138	139	140
f) Reliability Forecasting	141	142	143	144
g) Materials Requirements planning	145	146	147	148
h) Other (specify)				
149	150	151	152	153
154	155	156	157	158

Comments: _____

_____

_____

8.a. Please rate your total CAD/CAM installation in terms of it meeting your expectations at the time of purchase (on a scale of 1 - 10)

1 - 10 1 = totally fails to meet expectations

5 = equals expectations

10 = far exceeds expectations

Rating _____ 159

b. Explain all scores of 4 or less: _____

_____

_____

c. If you were to start over again today, would you buy from the same vendor(s)?

Yes _____ No _____ 160

d. If "no", why not? _____

_____

9. Please rate the importance of the following benefits of CAD in cost justifying the system. Rate on a scale of 1 to 10, where 1 is not important and 10 is of vital importance.

Benefit	Rating
a. Productivity improvement due to cost savings.	_____ 161
b. Design quality (better product)	_____ 162
c. Designs cannot be done without CAD/CAM	_____ 163
d. More efficient plant loading	_____ 164
e. Manufacturing efficiency	_____ 165
f. Employee morale	_____ 166
g. Better field maintainability	_____ 167

10.a. What are your planned expenditures for external CAD/CAM products and services for the following time periods? ($ in thousands-K or millions-M)

ITEM OF EXPENSE	1981	1982	1983
a) Hardware	168	169	170
b) Software	171	172	173
c) Remote Computing Services	174	175	176
d) Turnkey Systems	177	178	179

b. What is the average cost per workstation for your CAD/CAM system?

$ _____ K 1981 (180) $ _____ K 1986 (181)

c. What is the average cost per hour per workstation for use of the system?

1981 _____ $/hr/workstation (182) 1986 _____ $/hr/workstation (183)

11. What additional external CAD/CAM purchases for products or services do you expect to make by 1986?

a. Hardware (184) _____

_____

b. Software (185) _____

_____

c. Remote Computing Services (186) _____

_____

d. Turnkey Systems (187) _____

_____

e. Other (188) _____

_____

12. In your opinion, what will be the average annual growth rate for dollars spent on CAD systems and services in the U.S. between 1981 and 1986?

_____ $ AAGR
189

II. TECHNOLOGY ISSUES

13.a. What display terminal technology best serves your applications needs today and in 1986. Please rate on a scale of 1 to 10, where 10 is far exceeding application needs and 1 is totally inadequate for application needs.

TYPE	RATING 1981	RATING 1986
STORAGE TUBE	190	191
REFRESH:		
VECTOR STROKE (Calligraphic)	192	193
RASTER SCAN	194	195
HYBRID	196	197

b. In rating the types of display, considering the ability of the display to meet your application needs, how important are memory requirements? Please rate on a scale of 1 to 10, where 10 is very important and 1 is not a consideration at all.

	1981	1986
Rating	198	199

c. How important is price in the decision to select a particular display technology?

	1981	1986
Rating	200	201

d. What major changes in display terminals do you expect over the next 5 years, and why will the changes come about?

202 _____

_____

_____

14. IMPORTANCE OF COLOR

a. Are color displays a requirement?

1981 _____ Yes _____ No 203

1986 _____ Yes _____ No 204

Why? 205 _____

_____

_____

b. On a scale of 1 - 10, how important is color to your application needs? (1 = no requirement, 10 is absolutely essential)

Rating

1981 _____ 206

1986 _____ 207

Comments: 208 _____

_____

_____

15. What is the CAD workstation display resolution of your present system?

_____ 209 by _____ 210

_____ 211 by _____ 212

_____ 213 by _____ 214

16. RESPONSE TIMES

a. What response times are you presently experiencing on your present system?

_____ Seconds
215

b. Is this adequate?

_____ Yes _____ No 216

c. If no, what are your requirements?

_____ Seconds
217

d. Comments: 218 _____

_____

_____

17. VOLUMETRIC MODELING

a. Do you currently use solid/volumetric modeling techniques at your CAD workstations?

Yes _____ No _____ 219

Why or why not? 220 _____

_____

b. Do you expect to be using solid/volumetric modeling techniques at your CAD/CAM installation by 1986?

Yes _____ No _____ 221

18. How essential to your application, now and in 1986, are the following functions of CAD/CAM systems. Please rate on a scale of 1 to 10, where 10 is absolutely vital and 1 is no requirement.

FUNCTION	RATING 1981	RATING 1986
a. True 3-dimensional geometry	222	223
b. Dynamic motion	224	225
c. Modeling capability such as Finite Element Modeling	226	227
d. Numerical Control (N/C) machine control program generation	228	229
e. Statistical data and report generation	230	231
f. Interface of CAD to scheduling and costing function	232	233
g. Group technology for classifying groups of parts	234	235
h. Material requirements planning	236	237
i. Factory data collection system	238	239
j. Process and routing system	240	241

19. How likely is it that CAD/CAM systems will render conventional manufacturing drawings obsolete:

1 - 10

1 = impossible

5 = 50/50 chance

10 = absolutely certain

1983 _____ 242

1986 _____ 243

1990 _____ 244

20. How long does it take to train a new user of the CAD/CAM system?

a. To initial use _____ weeks
245

b. To complete proficiency _____ weeks
246

21. Would lower CAD/CAM system prices enable you to use these systems more extensively?

Yes _____ No _____ 247

Why or why not? _____
248

_____

_____

22. USE OF CAD

a. Where are your workstations located?

I. Central design facility _____
249

II. Co-located with design groups _____
250

b. Who operates CAD?

I. Specialist _____
251

II. Engineer _____
252

III. PRODUCTIVITY IMPROVEMENTS

23.a. What percent productivity improvement did you expect from your system?

_____% (253)

b. Overall, what percent productivity improvement has your CAD/CAM system provided over the previous method?

_____% (254)

c. How do you measure productivity gains associated with CAD/CAM implementation?

_____ (255)

_____

_____

_____

_____

24. What has been the productivity gain associated with the following components of the product development cycle which are attributed to your CAD/CAM system?

a. The most productivity gain

1. Design _____% (256) 2. Drafting _____% (257) 3. Engineering Analysis _____% (258)
4. Production planning _____% (259) 5. N/C programming _____% (260)
6. Documentation configuration control _____% (261)
7. Other (specify) _____ (262) _____% (263)

b. Comments: _____

_____

IV. SOFTWARE

25. ENHANCEMENTS

a. How are systems and applications software enhancements provided for your CAD/CAM system? Please rank in order of importance on a scale of 0 to 1, where 1 is most important.

	Ranking
1. In-house software development group	____ 264
2. Vendor software releases	____ 265
3. Software consulting services	____ 266

b. Do you belong to a users group?

Yes _____ No _____ 267

if yes;

- What is the name of the group?

_____ 268 name

Describe the group's goal/function: _____

_____

- How would you rate the overall effectiveness of the group in achieving its goals? (On a scale of 1 to 10, 10 = totally effective, 1 = totally ineffective) _____ 269 rating

c. What degree of participation do you have in IPAD?

- None ____ 270
- Observer status ____ 271
- Participant ____ 272
- Contributor ____ 273

What degree of participation do you have in ICAM?

- None ____ 274
- Observer status ____ 275
- Participant ____ 276
- Contributor ____ 277

Comments: _____

25. (Cont.)

d. Between the National Bureau of Standards' ANSI standard (Initial Graphics Exchange (IGES)), and the SIGGRAPH-CORE standard, which do you feel will become the final standard?

IGES	SIGGRAPH-CORE	COMBINATION OF BOTH
☐	☐	☐
278	279	280

Comments: _____

_____

_____

_____

26. Please identify which CAD/CAM software packages and documentation you use (or utilities used in CAD/CAM environment). Rate them on a scale of 1 to 10, where 10 is outstanding and 1 is completely inadequate.

SOFTWARE PACKAGE	USE YES	USE NO	RATING APPLICATION
a) CADAM 281			282
b) BOSOR (structural) 283			284
c) NASTRAN (structural) 285			286
d) SINDA (thermal) 287			288
e) AD 2000 289			290
f) OTHER 291			292
g) 293			294
h) 295			296
i) 297			298

27. OVERALL SOFTWARE EVALUATION

a. Please rate the overall adequancy of your CAD/CAM software today and what it is expected to be in 1986. Rate on a scale of 1 to 10, where 10 is excellent and 1 is very poor.

_____ 1981 (299) _____ 1986 (300)

b. What software requirements of your application are not being met by vendors, or by your in-house software development group?

(301)

V. CAD/CAM INTEGRATION

28. STATUS OF CAD/CAM INTEGRATION

a. How far has industry progressed toward CAD/CAM integration now, and how far do you expect it to be in 1986? Please rate on a scale of 1 to 10, where 10 is completely integrated systems and 1 is no progress at all.

	1981	1986
Rating	_____ 302	_____ 303

b. To your knowledge, what results have actually been obtained towards integrating CAD and CAM?

_____ 304

_____

_____

29. Is there or will there be a trend towards integrating design engineering data bases with:

		1981		1986		
a)	production	305 Yes _____	No _____	Yes _____	No _____	306
b)	quality control	307 Yes _____	No _____	Yes _____	No _____	308
c)	finance	309 Yes _____	No _____	Yes _____	No _____	310
d)	marketing	311 Yes _____	No _____	Yes _____	No _____	312
e)	purchasing	313 Yes _____	No _____	Yes _____	No _____	314
f)	research and development	315 Yes _____	No _____	Yes _____	No _____	316
g)	other _____ 317	318 Yes _____	No _____	Yes _____	No _____	319

Why will this design engineering data base (not) take place with other functional data bases?

_____ 320

_____

30. How will the trend towards engineering and manufacturing data base integration change organizational responsibility in:

a) design engineering _____ 321

_____

b) production planning and control _____ 322

_____

c) factory operations _____ 323

_____

d) traditional DP functions _____ 324

_____

31. Please rate the following in terms of their being an obstacle to an integrated CAD/CAM data base. Please rate on a scale of 1 to 10, where 10 is a very large obstacle and 1 is no obstacle at all.

lack of standards _____ 325

too much complexity _____ 326

incompatible systems components _____ 327

concern over data securiy _____ 328

costly implementation _____ 329

organizational conflicts _____ 330

benefits not proven _____ 331

other (please specify) _____ 332 _____ 333

32. Will distributed data bases for design engineering data and manufacturing operations data be developed for integrated CAD/CAM installations?

1981 Yes _____ No _____ Don't know _____ 334

1986 Yes _____ No _____ Don't know _____ 335

33. How important is it to make provisions for data security in CAD/CAM systems? Please rate on a scale of 1 to 10, where 10 is essential and 1 is of no importance.

	1981	1986
Rating	_____ 336	_____ 337

b. What are the needs for data security?

_____ 338

_____

_____

c. What provisions do you expect to utilize for CAD/CAM data security?

_____ 339

_____

_____

34. Will text processing capabilities have to be included in CAD/CAM systems?

Yes _____ No _____ 340 Why or why not? _____

_____

_____

VI. MAINTENANCE

35.a. Is your hardware maintained through:

_____ (341) A monthly maintenance contract $ _____ (342) /month

_____ (343) A time and materials arrangement $ _____ (344) /month averaged

_____ (345) In-house personnel _____ (346) number

b. Is the software supported through:

_____ (347) A monthly maintenance fee $_____ (348) /month

_____ (349) A time and materials arrangement $ _____ (350) /month averaged

_____ (351) In-house personnel _____ (352) number

_____ (353) No charge

36. How would you rate the overall quality of the maintenance you receive? Please rate on a scale of 1 to 10, where 10 is superior and 1 is completely inadequate.

Hardware _____ (354) Software _____ (355)

If less than 4, comment. (What has the vendor promised to do that he is not doing?)

_____

_____

_____

37. What levels of response are you presently receiving for the following maintenance characteristics?

	Actually Experienced		Minimum Acceptable	
	Hdwre	Sftwre	Hdwre	Sftwre
a. Mean time to respond (hours)	356	357	358	359
b. Mean time to repair (hours)	350	361	362	363
c. MTBF (hours)	354	355	366	367
d. Percent uptime (%)	368	369	370	371

38. What percent of the total purchase decision for future CAD/CAM systems will be based on the quality of maintenance service a vendor provides?

_____ %
372

VII. CAD/CAM SUPPORT OF BUSINESS GRAPHICS

39. COMPUTER BUSINESS GRAPHICS

a. Please rate the importance of CAD/CAM as the basic capability that allows an extension into computer business graphics, now and in 1986. Please rate on a scale of 1 to 10, where 10 is most important and 1 is not important at all.

	1981	1986	Don't know
Rating	_____ 373	_____ 374	_____ 375

b. Is your company using computer business graphics today? If not, will business graphics be in use in 1986?

	1981	1986
Yes	376 _____	_____ 377
No	_____	_____

MECHANICAL VENDOR OUTLINE

I. GENERAL

II. MARKET GROWTH

III. TECHNOLOGY ISSUES

IV. PRODUCTIVITY IMPROVEMENTS

V. SOFTWARE

VI. CAD/CAM INTEGRATON

VII. MAINTENANCE

I. GENERAL

1. For the purpose of this study, INPUT defines "CAD" as the utilization of computer aids for graphics, analysis, simulation, modeling requirements, documentation and configuration control in the support of the design function. "CAM" is defined as the utilization of computer aids in the linkage of outputs from design into the manufacturing process through direct control of numerical control equipment, documentation to aid N/C programmers, bills of material, quality control and the mutual exchange of data between manufacturing and design requirements.

2. What type of CAD/CAM systems, services, or software do you offer?

TYPE	PROVIDED (X)	RATING 1981	RATING 1986
a. Standalone turnkey system	10	11	12
b. Integrated system tied to data base	13	14	15
c. Software for in-house host system	16	17	18
d. Remote computing services	19	20	21
e. Independent CAD/CAM software packages	22	23	24
f. Other _____	25 26	27	28
g. Other _____	29 30	31	32

Please rate the above type of systems with respect to what you believe will be the most dominant method of delivering CAD/CAM capability, now and in 1986. Rating on a scale of 1 to 10, where 10 is most prevalent method and 1 is least prevalent method

Comments: _____

_____

3. Will you please send a copy of your latest product/services literature and price list to:

INPUT
2471 East Bayshore Road, Suite 600
Palo Alto, CA 94303

4. Will you please furnish us with a list of your users?

5. What percentage of your products/services do you sell directly to end-users?

33 _____%

II. MARKET GROWTH

6. What is the distribution of your installed CAD/CAM systems in the U.S.A. for the following applications:

APPLICATION	1981	1986
ELECTRONIC	34 ____ %	35 ____ %
MECHANICAL	36 ____ %	37 ____ %
CIVIL/STRUCTURAL	38 ____ %	39 ____ %
MAPPING	40 ____ %	41 ____ %
OTHER ____	42 ____ %	43 ____ %
	100 %	100 %

7. What is your presently installed base of CAD/CAM systems today.

APPLICATION	NUMBER OF SYSTEMS/ SERVICES	$ VALUE OF SYSTEMS/ SERVICES
ELECTRONIC	44	45
MECHANICAL	46	47
CIVIL/STRUCTURAL	48	49
MAPPING	50	51
OTHER 52 ____	53	54
TOTAL	55	56

8. In your opinion, what will be the average annual growth rate (AAGR) for dollars spent on CAD systems and services in the U.S. between 1981 and 1986.

	AAGR
Electronic 57	____%
Mechanical 58	____%
Civil/Structural 59	____%
Mapping 60	____%
OVERALL 61	____%

Comments: 62 _____

_____

_____

9. For your product/service segment, what share of the market do you have/expect to have?

Present share 63 ____% 1986 share 64 ____%

10. What is the average cost per workstation for your system?

65 $____ K's 1981 66 $____ K's 1986

11. What is the average cost per hour per terminal for use of the system?

67 ____ $/hr/terminal 1981 68 ____ $/hr/terminal 1986

12. Please rate the importance of the following benefits of CAD in cost justifying the system. Rate on a scale of 1 to 10, where 1 is not important and 10 is of vital importance.

Benefit	Rating
a. Productivity improvement due to cost savings.	_____ 1M
b. Design quality (better product)	_____ 2M
c. Designs cannot be done without CAD/CAM	_____ 3M
d. More efficient plant loading	_____ 4M
e. Manufacturing efficiency	_____ 5M
f. Employee morale	_____ 6M
g. Better field maintainability	_____ 7M
h. Other _____	_____ 8M
i. Other _____	_____ 9M
j. Other _____	_____ 10M

13. Who are your top three competitors today and in 1986. Please rank in order from 0 to 1, with 1 being foremost competitor.

COMPETITOR (NAME)	RANK
69	70
71	72
73	74

Comments: 75 _____

_____

_____

II. TECHNOLOGY ISSUES

14. What display terminal technology best serves your applications needs today and in 1986. Please rate on a scale of 1 to 10, where 10 is far exceeding application needs and 1 is totally inadequate for application needs.

TYPE	RATING 1981	RATING 1986
STORAGE TUBE	76	77
REFRESH:		
VECTOR STROKE (Calligraphic)	78	79
RASTER SCAN	80	81
HYBRID	82	83

b. In rating the types of display, considering the ability of the display to meet your application needs, how important are memory requirements? Please rate on a scale of 1 to 10, where 10 is very important and 1 is not a consideration at all.

	1981	1986
Rating	84	85

c. How important is price in the decision to select a particular display terminology?

	1981	1986
Rating	86	87

d. What major changes in display terminals do you expect over the next 5 years, and why will the changes come about?

88 _____

_____

_____

15. How important is the use of color in workstation display for the following applications? Please rate on a scale of 1 to 10, where 10 is of paramount importance, and 1 is not important at all.

APPLICATION	RATING	
	1981	1986
Electronic Design	89	90
Mechanical Design	91	92
Civil Engineering	93	94
Mapping	95	96

16. What response times are users of your systems generally experiencing?

97_____ seconds

b. Is this adequate?

98Yes _____ No _____

c. If no, what are the requirements?

99_____ Seconds

d. Comments:

100_____

_____

_____

17. For CAD/CAM design applications, which application input devices are most likely to be used in 1986 systems? (List percent of installations using these devices)

light pen _____%101 joystick/ball _____%102

keyboard _____%103 tablet _____%104

touch panel _____%105 digitizer _____%106

touch recognition _____%107 other _____108 _____%109

18. What will be the prevalent system architecture now and in 1986. Please rank in order of relative importance from 1 to 10, where 1 is most important.

CONFIGURATION	RANK ORDER 1981	RANK ORDER 1986
A. CPU AND GRAPHICS PROCESSOR CO-RESIDENT WITH THE WORK-STATION	_____110	_____111
B. CENTRAL MAINFRAME HOST AND REMOTE GRAPHICS PROCESSOR	_____112	_____113
C. DISTRIBUTED SYSTEMS	_____114	_____115
D. REMOTE COMPUTING SERVICES	_____116	_____117

19. What are the cost effective balances of intelligence between terminal, local processor and central processor:

Now 118 _____

_____

_____

And in 1986 119 _____

_____

_____

Comments: 120 _____

_____

_____

20.a. Do you offer end-user training on your CAD/CAM system?

Yes _____ No _____ 121

b. How long does it take to train a new user to:

1. Initial use _____ weeks 122

2. Complete proficiency _____ weeks 123

IV. PRODUCTIVITY IMPROVEMENTS

21.a. What percent productivity improvements do users expect from your system?

_____ % 11M

b. Overall, what percent productivity improvement has the CAD/CAM system provided over previous methods?

_____ % 12M

c. How do users measure productivity gains associated with CAD/CAM implementation?

13M _____

_____

_____

_____

_____

22. For which components of the product development cycle does the CAD/CAM system provide the most productivity gain?

	Percent of productivity gain
a. Design	_____ % 14M
b. Drafting	_____ 15M
c. Engineering Analysis	_____ 16M
d. Production planning	_____ 17M
e. N/C programming	_____ 18M
f. Documentation	_____ 19M
g. Configuration control	_____ 20M
h. Other (specify) _____ 21M	_____ 22M
TOTAL	100 %

23. In what fields have improvements in productivity been the greatest? Please rank order on a scale of 0 to 1, where 1 is the greatest improvement.

FIELD	RANKING
ELECTRONIC	_____124
MECHANICAL	_____125
CIVIL/STRUCTURAL	_____126
MAPPING	_____127

V. SOFTWARE

24. What application software do you currently offer for your turnkey CAD systems? (Please list by name and give end-user's purchase pricing)

Electronic 128 _____

_____

_____

Mechanical 129 _____

_____

_____

Civil/Structural 130 _____

_____

_____

Mapping 131 _____

_____

_____

25. What do you believe the major new software developments will be in 1986?

a. System software 132 _____

_____

_____

b. Application software 133 _____

_____

_____

26. Will independent software vendors have any impact upon CAD systems during the next several years?

Yes _____ No _____ 134

Rated on a scale of 1 to 10, how important are these vendors to the future of CAD/CAM systems?

_____ Rating 135

Comments: 135 _____

_____

_____

27.a. What impact, if any, will government-funded software development have on industry software developments? Please rate on a scale of 1 to 10, where 10 is a major impact and 1 is of no importance.

_____ Rating 23M

b. What software development programs are you aware of that have been sponsored by the U.S. Federal Government?

24M _____

_____

_____

c. Between the National Bureau of Standards' ANSI standard (Initial Graphics Exchange (IGES)), and the SIGGRAPH-CORE standard, which do you feel will become the final standard?

IGES	SIGGRAPH-CORE	COMBI-NATION OF BOTH
☐	☐	☐
137	138	139

Comments: _____

_____

_____

_____

28. How likely is it that CAD/CAM systems will render conventional manufacturing drawing obsolete?

1 - 10

1 = impossible
5 = 50/50 chance
10 = absolute certainty

1983 _____ 25M

1986 _____ 26M

1990 _____ 27M

V. CAD/CAM INTEGRATION

29. STATUS OF CAD/CAM INTEGRATION

a. How far has industry progressed toward CAD/CAM integration now, and how far do you expect it to be in 1986? Please rate on a scale of 1 to 10, where 10 is completely integrated systems and 1 is no progress at all.

	1981	1986
Rating	140	141

b. To your knowledge, what results have actually been obtained towards integrating CAD and CAM?

142 _____

_____

_____

30. What will be the requirements for design data and manufacturing operations data to be integrated to CAD data files. Please rate on a scale of 1 to 10, where 10 is absolute and 1 is not required.

Rating _____ 28M 1981 _____ 29M 1986

31. What engineering and manufacturing functions are most likely to utilize an integrated data base for CAD/CAM first in the mechanical industries? Please rate on a scale of 1 to 10, where 10 is most likely and 1 is very unlikely.

design _____ 30M

assembly _____ 31M

drafting _____ 32M

test and inspection _____ 33M

planning and control _____ 34M

materials handling _____ 35M

fabrication _____ 36M

other (specify) _____ 37M

_____

Comments: 38M _____

_____

_____

_____

_____

32. How will the trend towards engineering and manufacturing data base integration change organizational responsiblity in:

a) design engineering 39M _____

_____

b) production planning and control 40M _____

_____

c) factory operations 41M _____

_____

d) traditional DP functions 42M _____

_____

33. Please rate the following in terms of their being an obstacle to an integrated CAD/CAM data base. Please rate on a scale of 1 to 10, where 10 is a very large obstacle and 1 is no obstacle at all.

lack of standards _____43M

too much complexity _____44M

incompatible systems components _____45M

concern over data securiy _____46M

costly implementation _____47M

organizational conflicts _____48M

benefits not proven _____49M

other (please specify) _____50M _____51M

34. Will distributed data bases for design engineering data and manufacturing operations data be developed for integrated CAD/CAM installations?

1981 Yes _____ No _____ Don't know _____52M

1986 Yes _____ No _____ Don't know _____53M

VII. MAINTENANCE

35. Do you offer hardware maintenance through:

_____143 A monthly contract $_____144/month

_____145 A time and materials arrangement $_____146/month averaged

_____147 Contract with third party

_____148 Do not offer hardware maintenance

_____149 Other (please specify) 150_____

_____

36. Is the software supported through:

_____ 151 A monthly maintenance fee $_____ 152 /month

_____ 153 A time and materials arrangement $_____ 154 /months averaged

_____ 155 No charge

_____ 156 Do not offer software maintenance

_____ 157 Not applicable to our products/services

_____ 158 Other (please specify) 159 _____

_____

37. How would you rate the overall quality of the maintenace you provide? Please rate on a scale of 1 to 10, where 10 is superior and 1 is complete inadequate.

Hardware _____ 160 Software _____ 161

If less than 4, comment. (What do the users request that is not being provided)

162 _____

_____

_____

38. What levels of response are you presently providing for the following maintenance characteristics?

	Actually Experienced		Minimum Acceptable	
	Hdwre	Sftwre	Hdwre	Sftwre
a. Mean time to respond (hours)	163	164	165	166
b. Mean time to repair (hours)	167	168	169	170
c. MTBF (hours)	171	172	173	174
d. Percent uptime (%)	175	176	177	178

39. What percent of the total purchase decision for future CAD/CAM systems will be based on the quality of maintenance service a vendor provides?

_____ %
179